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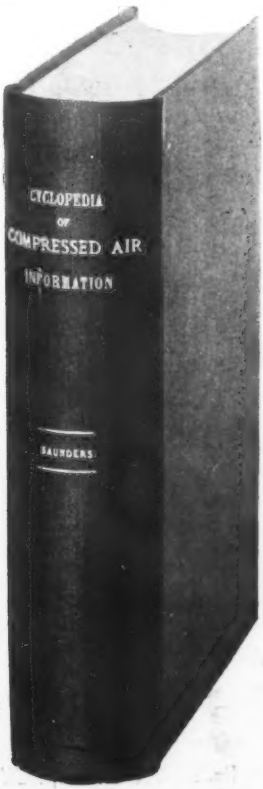
Compressed Air

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. VII. NEW YORK, JUNE, 1902. No. 4.



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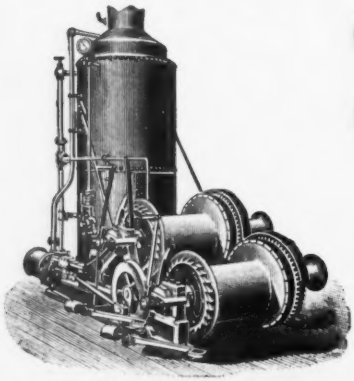

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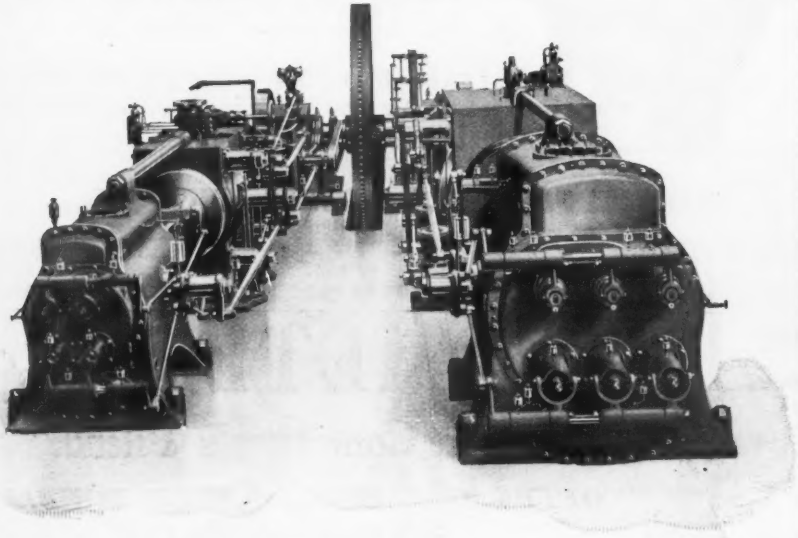

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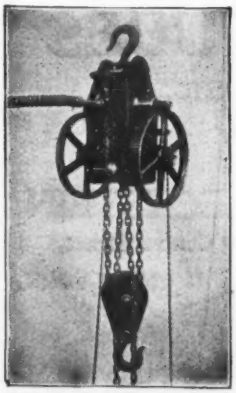

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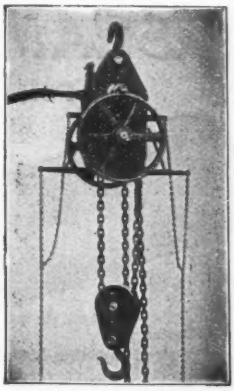

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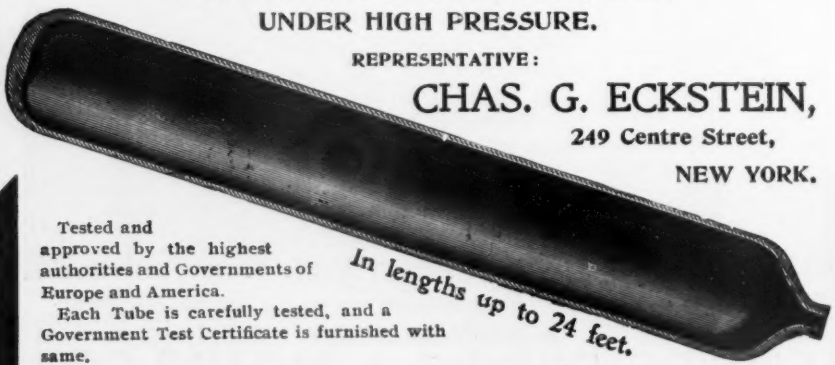

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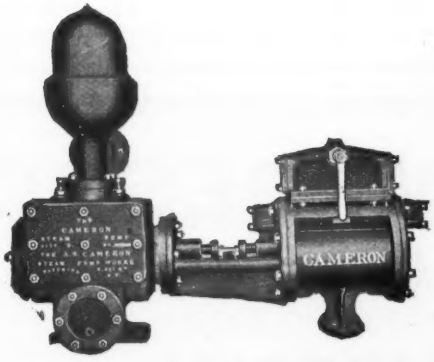

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VOL. VII. JUNE, 1902. NO. 4.

The volumetric efficiency of air compression cylinders is a subject that has for some time past been the basis for much discussion, especially among those closely connected with this branch of engineering. Claims of relatively high efficiencies for different makes of compressors have been made and as often disputed, until the purchaser, who is not generally endowed with a knowledge of the thermodynamics of air compressors and often simply looks upon the installation of such machines as an economical means to an end, is unreasonably biased in favor of one style, or, if he has used good judgment, and, as it were, taken some salt with what he hears, is at best more or less at sea and unable to decide as to the relative merits of the different makes.

The question that becomes of real importance is, what effect has the volumetric efficiency upon the first cost, and also upon the cost of operation, and this must be viewed from a point of the total economy extending over the life of the machine. The first of these questions almost answers itself. Of two compressors operating at the same speed and having equal piston displacement capacities, the one having the higher volumetric efficiency will deliver the most compressed air, or, in other words, the one having the lower volumetric efficiency must, to deliver an equal amount of air, be a larger machine at a corresponding advance in cost, all other conditions being equal.

The second of these questions, as to the effect on cost of operation, involves a complete study of the several changes in temperature, pressure and volume that the air undergoes during compression, discharge and admission before one should pass judgment. No attempt will be made here to go over the ground in full detail, but a few reminders may not be amiss to illustrate the importance of what are sometimes considered small points.

In a cylinder sufficiently jacketed, both in the heads and around the bore, it cannot be assumed that the air left in the clearance space upon re-expanding will regain all the heat delivered during compression, and the loss here would argue for a small per cent. of clearance, yet to prepare the cylinder for the new charge of air to be taken in, which we will assume is practically at the surrounding atmospheric temperature, the cylinder should be brought as near that temperature as possible, and the larger the amount of air re-expanding and absorbing heat, the lower the cylinder temperature during the intake period. On account of the practical difficulties to be met in attempting to observe the varying temperatures occurring inside such a cylinder, no actual data on this point having come under the writer's notice, a concensus of gen-

eral opinions must be taken, and this seems to be that in compressors running at the rated speeds in vogue at present there will be but a comparatively slight variation in the temperature of the air cylinder where the ratios of compression are not excessive. If such is really the case, the clearance space should be kept small, as no advantage is to be gained from its being made greater.

The results of a careful test to determine the volumetric efficiency of a compressor of standard make are given in this issue and will be read with interest.

Volumetric Efficiency of an Air Compressor Cylinder.

In regard to the volumetric efficiency of the piston inlet valve tyne of air cylinders used on the Ingersoll-Sergeant Drill Co.'s Straight Line Class "A" Compressors.

The general construction of this type of air cylinder is shown in the accompanying cut, Fig. 1, from which it will be seen that the clearance space is reduced to the least possible amount, the following conditions favoring this form over any other.

The piston valve being part of the piston, has, as is shown, a circular ring of metal about 5-32 inch thick protruding from the ends of the piston and a corresponding groove cut in the heads of the cylinder to receive this ring, allowing only tne same clearance distance that is allowed the piston itself. The degree to which this clearance can be reduced is limited by the following conditions, which necessarily exist in all air-compression cylinders. This cylinder of compression when just starting up is comparatively cold, it being at the temperature of the atmosphere, upon running up to pressure for some little time, it becomes heated up to somewhere near the temperature of compression, which, in a cylinder compressing from atmospheric pressure to

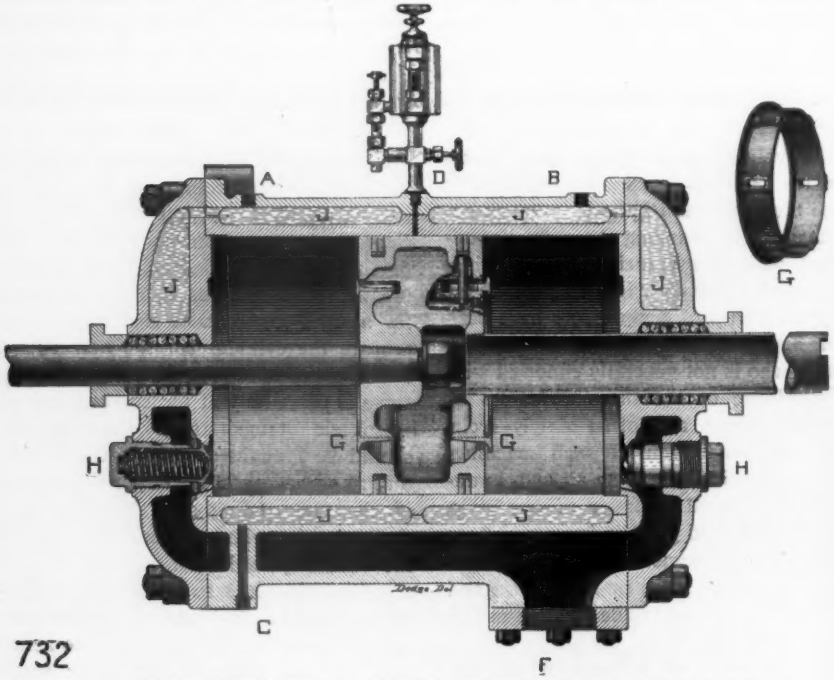


FIG. I.—DETAILS OF AIR CYLINDER, SHOWING PISTON INLET VALVE.

100 pounds, is approximately 400 degrees F. This change in temperature is accompanied by a corresponding expansion of the several parts coming in contact with the heated air, of which the piston rod and piston probably show the greatest effect, this expansion of the rod being so great in some cases that a piston set to just hit the front head of the compressor when cold will hit the back head when running up to pressure and the exact amount of clearance to just avoid hitting the heads has been determined for the above make of compressors and approximates 1-16 in. on each end of the cylinder.

Confining the discussion to one size of cylinder, namely, the 24¼ in. diameter x 30 in. stroke air cylinder on the Class "A" Straight Line Compressor No. 4371. Inspected and tested Nov. 29, 1901, so that the results can be attested to as being taken under actual running conditions, and not as general results, which though they are such, and indicate what can be looked for in this type of air cylinder, it has been thought best to found this statement on facts and not generalities.

Expressing the clearance in per cent. of the total cylinder volume displaced by the piston during one stroke, we have for the above cylinder 47-100 of 1 per cent. and from simply figuring this as re-expanding a volumetric efficiency of 96.4 per cent. is obtained.

Without due consideration one might think this figure higher than that actually obtained in practice, but by taking up the several effects as they occur in the cylinder, it seems to be a close approximation. See results of volumetric tests.

The volumetric efficiency of an air cylinder depends entirely upon the conditions affecting the intake stroke, during which air is admitted to the cylinder. Any air which remains in the clearance space at the pressure and temperature of discharge must re-expand until the pressure drops below that of the atmosphere, before a flow of air into the cylinder can be obtained. This re-expansion is accompanied by a drop in temperature and a consequent contraction in volume over that figured from simple re-expansion. After the line of re-expansion crosses the atmospheric line the flow of new air into the cylinder takes place, and during this period one of the most important features of the piston inlet type of valve is brought into play. That of allowing the air to enter the cylinder with the least resistance, the frictional surfaces presented being less than in any other form of inlet valve up to date. A peculiarity noticeable on these cards is the rise in pressure at the end of the intake stroke caused by the velocity of the inrush air during the intake period, continuing while the piston slows down and passes over the dead center. This is caused by the air entering in one large column, it being broken up into several smaller columns in other types of valves. This peculiarity insures a full cylinder of air at approximately atmospheric pressure (see cards).

A set of indicator cards for this compressor taken at random from the files of record cards which are taken during the regular course of inspection of the air compressors of this make, show the following results. See Fig. 2 for exact reproduction of these cards taken at ½ cut-off on steam end.

Now marking off where the re-expansion line crosses the atmospheric line and finding the length, A, dividing it by B and correcting it for the difference from the atmospheric pressure existing at the end of the inlet stroke, we have the volumetric

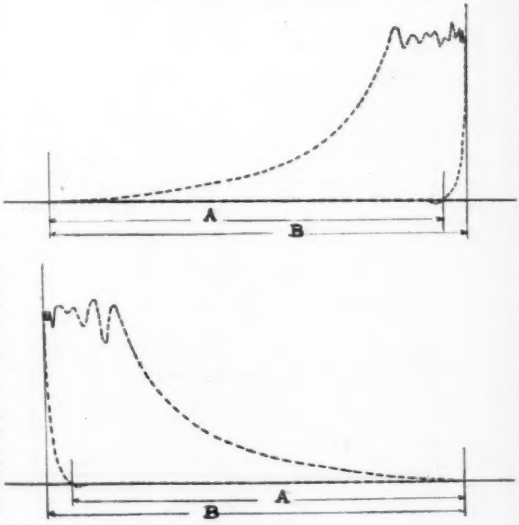


FIG. 2.

STEAM PRESSURE—103 LBS.
AIR PRESSURE—100 LBS.
REV. PER MIN.—82.

efficiency as exactly as it can be figured, and several volumetric tests with a meter attached have checked this method of figuring, giving the proper allowance to be made when using this method.

Volumetric efficiency figured thus = 94.4 for the 24 and 24¼x30 in. Class "A" Compressor in question.

To illustrate the gain in volumetric efficiency realized at lower discharge pressures with cylinders having this type of inlet valves, cards taken from the low pressure cylinder of the 22" and 24¼" and 16" x 24" stroke Class A. C. Ingersoll-Sergeant Compound Compressor or No. 2959 are shown in Figs. 3 and 4.

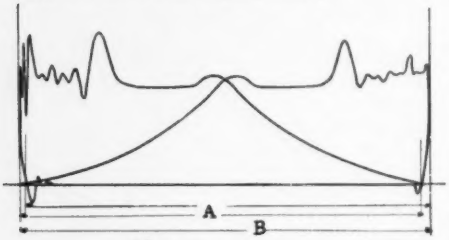


Fig. 3

HIGH PRESSURE—100 LBS.
INTERMEDIATE PRESSURE—22 LBS.
SPEED—96 REV. PER MIN.

This Compressor is designed for a final discharge pressure from 80 lbs. to 100 lbs., the intermediate or low pressure cylinder discharge pressure being 22 lbs. The cards in Fig. 3 were taken at a speed of 96 R. P. M., and figuring the volumetric efficiency as above we get for this cylinder 98.1%. Those in Fig. 4 were taken at a speed of 60 R. P. M., and give a volumetric efficiency of 98.3%, a slight increase due to the lower speed.

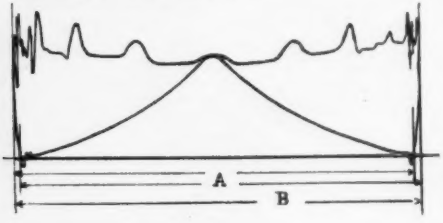


Fig. 4.

HIGH PRESSURE—100 LBS.
INTERMEDIATE PRESSURE—22 LBS.
SPEED—60 REV. PER MIN.

The meter tests for volumetric efficiency referred to were of several weeks' duration, different arrangements of the compressor, coolers, receivers, meter, etc., being tried until the arrangement described below was adopted as that giving the most accurate results.

The compressor, the same size and style as the one already discussed, was connected up for testing in the usual way, the air being taken from the room and not from some outside source. The discharge was first run through an aftercooler where its temperature was reduced to about the same as that of the room itself. From this cooler it passed into a large receiver, thence through a 4" gate valve No. 1 to a second smaller receiver, and from there to the meter, after which it passed through another 4" valve No. 2, to the discharge line, being then discharged into the atmosphere.

Gauges were placed on the large receiver and both immediately before and after the meter. Thermometers were placed before and after the after-cooler and also before and after the meter. A continuous counter was attached to the compressor to accurately record the exact number of revolutions. Indicator cards were also taken at intervals of 5 minutes with the other readings of the meter gauges, thermometers, etc.

The exact procedure during the tests was as follows:

The compressor was started up and valve No. 1 throttled down until the pressure ahead of this valve was 100 lbs., and the speed 80 R. P. M., then valve No. 2 was throttled down to a convenient pressure below 100 lbs., it being varied through several different tests but always kept at a constant pressure during each test; this second pressure was alternately made 60 lbs., 70 lbs. and 80 lbs., to determine if any variation would occur in the results on account of the pressure variation. The results, however, when corrected for the difference in pressure were approximately the same. It may not be clear to the reader just why the above arrangement of the apparatus was adopted, but a consideration of one fact will clear this up. The meter used was one of the Equitable Meter Company's make, having a capacity of 20,000 cu. ft. of air per hour, and was found to only give accurate results when the flow and pressure of air passing through it re-

mained constant, any variation in these causing the diaphragm governing arrangement to oscillate and thus cause an erroneous reading to be recorded.

A short summary of the results of tests taken with compressor at 80 R. P. M., and compressing air to 100 pounds are as follows:

Average speed	79.8 R. P. M.
Average temperature of room	72° F.
Average tem. of air before cooling	412° F.
Average tem. of cooling water	55° F.
Average tem. of air before meter at 60 lbs.	69° F.
Average tem. of air after meter at 60 lbs.	69° F.
Average pressure, high	100 lbs.
Average pressure, low, varied as given in the several tests, 60, 70 and 80 pounds.	
Average volumetric efficiency as recorded by meter	90.2%
Correcting for meter which upon calibration was found to read 8% low, the volumetric efficiency becomes	98. %
Allowance to be made when using the card method	3.6%

This only refers to this type and size of cylinder at 100 pounds pressure, and the allowance for different pressures and other types must be determined by separate tests.

FRED'K V. D. LONGACRE, M. E.

Compressed Air in Mines.

The transmission of power has in certain directions serious competitors, in favor of which there has frequently been urged greater economy in first cost, in working cost, in efficiency, and in applicability. These claims are, however, keenly contested by advocates of compressed air, who, on the other hand, contend that it supplies a means of power transmission at once safe, economical, and efficient for general mining work. The force of this contention has been much increased recently by reason of the notable improvements effected in the methods of generating and transmitting air. In this connection I cannot do better than draw your attention to some remarks by Mr. J. H. Ronaldson, who points out that it is necessary to an intelligent appreciation of the subject to consider the laws relating to air as a gas.

"*Laws Affecting the Compression of Air.*—Air is an elastic fluid, which, when free from vapor, behaves as a perfect gas. 13.09 cubic feet at ordinary atmospheric pressure, and at 60 degrees Fah., weigh 1 lb. According to Boyle's law, the volume of a gas varies inversely as the pressure affecting it, so long as the temperature remains constant; consequently, in doubling or trebling the pressure, the volume becomes one-half or one-third respectively. According to Charles' law, if the volume of a gas be kept constant, the pressure varies as the absolute temperature, and if the pressure be kept constant, the volume varies as the absolute temperature. By the law of the transmutation of energy, work performed on a body, whether solid, liquid, or gaseous, is evidenced by a definite decrease of temperature in that body, and we are familiar with that fact as shown in the simple laboratory experiment of exploding a small charge of guncotton in a strong glass cylinder, through the rapid heating of the air contained in it by a sudden jerk of a tightly-fitting piston. Consequently, when air is compressed, it is heated; when heated it expands, and the volume of air to be compressed is proportionately increased with a corresponding expenditure of the power required to compress it. Could the temperature of the air undergoing compression be kept constant (isothermal) during the process, and the heat taken up from it returned to the air during its expansion in the motor while doing work, all loss from this source would be avoided. This, however, is impossible, and the aim of modern compressors is to prevent an increase in the volume of the air by keeping down the temperature during the period of compression—that is, by approximating to what is termed isothermal process. It is clear that the least efficient compressor is the one in which no provision is made for cooling the air during the actual period of compression—that is, one working on what is termed the adiabatic process.

"*Air-compressors.*—Two forms of compressors are in use, in each of which a reduction of the temperature of the air is aimed at—in one case by the use of a liquid piston in the cylinder, and in the other way by a water-jacket around the cylinder, or by an internal spray of water. The former is termed a 'wet' and the latter a 'dry' compressor.

"*Wet Compressors.*—Of these there are

two types: (*a*) Where the water-piston owes its energy to the fall of water from a height; (*b*) where the water is actuated by a steam-driven piston. At Mount Cenis, Mons. Sommeiller made use of water, with a fall of 86 ft., and, by utilizing the momentum of the falling water, he was able to obtain an air-pressure of 75 lbs. per square inch. Though extremely low in efficiency (not more than 6 per cent.), and necessitating clumsy plant, the arrangement gave results sufficiently good. This principle has been applied in other cases, and one arranged by Hathorn, Davey & Company, Leeds, was successfully used for many years in Mexico. The application of the principle is simple, and, where an abundant water-supply exists, excellent results are obtained. The second form of wet compressor has attained a wide application on the continent of Europe, where, particularly among the highly-educated Belgian and French engineers, the principles of air-compression are thoroughly understood. It is, however, a question if their adherence to this method is not an instance of the length to which a desire to reach an ideal perfection may lead one from the best practical solution of a problem. As will be shown later on,the dead space at the end of the air-piston stroke is undesirable,and it was largely to eliminate this defect and to keep the air cool that liquid pistons had such a vogue on the Continent. The water forced back and forward in the cylinder and up the pipe at each end, carrying the necessary valves, filled the dead space. But, unfortunately for this ideal, there are a number of inconveniences attendant on the system. The cooling of the air is insufficient, because it is only on the surface of the water. The speed of the piston is extremely limited, and cannot exceed 40 ft. to 50 ft. per minute, on account of the mass of water to be moved; consequently, the number of compressors required for a given work is large. The water agitated by the motion is frothed, and causes an excessive moisture in the air. Various devices, more or less successful, have been used to lessen these defects; but, in spite of all, the fact remains that in other countries these compressors have not found favor.

"*Dry Compressors.*—This type of compressor has a cylinder and piston similar to those of a steam-engine, with suitable outlet and inlet valves at the cylinder ends. The temperature of the air is kept within reasonable limits by the constant flow of cold water through the water-jacket of the cylinder from the bottom upwards. It is, however, doubtful if the process of cooling, even under the most favorable conditions, does more than keep the cylinder from becoming excessively heated, and so imparting heat to the incoming air. A more thorough method of cooling is obtained by injecting a fine spray of cold water into the cylinder near the outlet valves. To this the objection has been strongly urged that the presence of water, with its non-lubricating properties, causes an undue wear and tear in the cylinder, and loss in power.

"*Causes of Low Efficiency in Air Compressors.*—These causes, briefly stated, are the heating of the air during compression, mechanical defects in the inlet and outlet valves, and leakage past the piston. It has been already shown that air, when subjected to compression, is heated, and that, as the volume is thereby increased, much power is uselessly expended in dealing with the heated air. The most efficient compressor, therefore, in this regard, must be the one presenting the best cooling arrangement for the air as it is being compressed. That form of compressor in which the piston is represented by the falling water supplying the power, such as Sommeiller's, permits of a very thorough cooling, as the water piston is renewed each stroke, and the cylinder is kept perfectly cool. But in the second form of wet compressor, such as Dubois', of Belgium, in which the water, only slightly renewed per stroke, becomes considerably heated, the cooling is not more perfectly effected than in the dry compressor. As the pressures to which the air is raised become greater, the losses from this source become serious, and as the efficiency of the motors increases with the pressure, and the sizes of the conduits can be correspondingly small, it is desirable, perticularly in large installations, to use high-pressure air. The most satisfactory results in this direction have been obtained by stage compression—that is, by pressing the air to a certain pressure in one cylinder, and further compressing it in a second, and, if desired, in a third, or even a fourth. By this system the air is cooled between each stage, and the losses from this source are minimized. For low pressure it is doubtful if any practical economy would result from stage compression,

but it is now fully demonstrated that for pressures above 60 lbs., the advantages of stage compression are very marked. To diminish the losses caused by resistance to the passage of the air through the inlet and outlet valves, many devices have been resorted to. In the ordinary valves held closed by springs, the valves rattle or chatter if the springs are weak. On the other hand, if the springs are made very strong, a resistance to the passage of the air is set up, resulting in a loss of power, which, in some cases, becomes serious. To obviate this defect, the valves are occasionally devised to open mechanically. In a short letter such as this it is impossible to enter into the details of the various valves used. It is not uncommon to hear much stress laid on the losses caused by the unavoidable dead space occupied by compressed air at the end of each stroke, and it may be pointed out at once that the loss is not in power, but solely in the volumetric capacity of the compressor. To diminish this inconvenience, the air-piston is usually run as close to the cylinder ends as practical, and care is requisite to avoid sailing too close to the wind in this direction, and damaging the mechanism. The best plan is to arrange trick passages, or grooves, on the inside of the cylinder, for a short distance back from each end, to allow the air in the dead space to pass the piston to the end in which compression is about to begin. The inside pressure against the suction valves is thereby relieved, and compression on the other side of the piston begins at once. To prevent knocking through the sudden relief caused thereby at the end of the stroke, a certain amount of cushioning in the steam cylinder is required. The low efficiency due to leakage in the pistons can only be effectually reduced by carefuly attending to their condition. Naturally, the higher the compression the greater the leakage, but stage compression greatly lessens this evil.

"*Air Conduits.*—Two considerations are of importance in determining the pipes to be employed; these are the size of the pipes, and the character of the joints. The frictional loss in the passage of the air through the pipes increases very rapidly as the diameter decreases, as shown by the following example:—If a volume of air at 60 lbs. pressure, equivalent to 18,000 cubic feet per hour, at atmospheric pressure be passed through 1,000 ft. of pipes, the loss of pressure of air for 2½ in., 3 in., 3½ in., and 4 in. pipes would be 5¾ lbs., 2 lbs., 1½ lbs. respectively. Leakage at the joints through the expansion and contraction of the pipes is a fruitful and, at times, a serious loss of power. A receiver of suitable size should always be placed alongside the compressor, and where a considerable length of pipes is used, it is an advantage to have a receiver as near the motor as practicable.

"*Method of Using Compressed Air.*—When air is compressed it is heated, and when it expands it is cooled. The latter fact gives rise to the inconvenience so frequently met with in air motors of ice being formed in the ports through the freezing of the moisture in the air. Where the air is admitted to the motor practically during the whole stroke, there is little danger of ice being formed, but there is a terrific waste of power, for it is as important for economy to use air expansively as it is to use steam expansively. While a little moisture in air used expansively results in the formation of ice in the ports, it may be pointed out that aqueous vapor has a specific heat nearly double that of air, and consequently cools less rapidly under expansion than dry air, and the tendency of an excess of moisture is to reduce the cooling. The specific heat of water being still greater, a spray of water may be effectively used in the motor cylinder to prevent cooling to the freezing point. The writer was familiar many years ago with an instance where, in the case of large haulage engines placed underground, the inconvenience caused by freezing was so serious that compressed air was abandoned, and steam, though inconvenient, was substituted. Reheating the air is, however, the most effective method of allowing air to be used expansively without the formation of ice in the ports, and this can best be done by passing the air near the motor through a coil of pipes heated by a small furnace; and a further elaboration, permitting the highest degree of expansion, is effected by introducing a small quantity of water into the heater, where it is converted into steam. A move in the latter direction was made years ago, by the use of a jet of steam in the air-pipe near the motor. In practice, it is found that reheating the air not only prevents freezing, but results in a very great economy in the use of compressed air, at a small cost both for plant and fuel.

"The Dangers Attending the Use of Compressed Air.—These are so slight as to be scarcely worth considering, but their existence is worthy of passing notice. A few cases are known where an explosion, more or less marked, has occurred in the receiver placed near the compressor. In these instances combustion has been set up, apparently, in the carbonaceous matter deposited from the lubricants used in the compressor. The readiness with which a piece of old oily waste takes fire at comparatively low temperature is well known, and it is possible that a similar action may take place in the deposited carbon, if subjected accidentally to abnormal heating, by a failure in the cooling apparatus of the compressor."—W. A. PHILLIPS, *in Iron and Coal Trade Review.*

Some Observations on the Deep Pneumatic Work of the New East River Bridge Foundations.

An article entitled "The Occurrence and Treatment of Caisson Disease in Engineering Works," has just come to the attention of the writer. As a statement is made in relation to the greatest air pressure used at the New East River Bridge which differs greatly from the fact and as some conclusions are based on this statement, it seems well that the real facts should be explained. The work in question was done under the immediate direction of the writer as Resident Engineer, and he is therefore very familiar with all the facts and conditions. An explanation was begun in the form of a "letter to the editor," but so many interesting points developed that it was thought better to put it in the form of a short general description of some special features of the work. The compressed air conditions met in the two Brooklyn piers were quite unusual and of sufficient interest to merit description, especially as these conditions may be assumed to apply in a greater or less degree to the numerous compressed air tunnels now projected under the East and North rivers. The north pier only will be described, as the conditions met at the south pier were very similar, though it was of somewhat less depth.

The article states "the work of excavation and of placing the concrete (at north Brooklyn pier, New East River Bridge) was performed at a depth of 108 ft. below water level, requiring an air pressure of 46½ lbs. per sq. in." This pressure seems obvious from the depth, except that it should be 48 lbs., because of sea water. As a matter of fact, however, the highest pressure ever used in this caisson was 38 lbs. per sq. in., and this only when the cutting edge first reached the depth of 90 ft. below mean high water. The pressure was then at once reduced to about 31 lbs. per sq. in. for a couple of days; then carried for the remainder of the pneumatic work (a period of over six weeks) at pressures of 33 lbs. to 37 lbs. per sq. in., the variations being irregular and the pressures not increasing with the depth.

The preliminary diamond drill borings showed above the clay about 50 ft. of water and about 20 ft. of sand with some boulders. The clay began at about 70 ft. below mean high water and extended without change to the rock, the highest point of which was found at a depth of 86 ft. and the lowest at a depth of 105 ft. The depths found by the diamond drill were in general corroborated by the more exact information secured during the sinking. This latter information showed that unless borings are taken very close to each other no inference is warranted as to the shape of the bed rock at intermediate points, at least with the gneiss rock of this neighborhood. The diamond drill borings and the sinking also showed that no reliance could be placed on wash borings to distinguish between boulders and bed rock. Seven wash borings had been made on and close to the tower site, each boring terminating on stone. A charge of dynamite was exploded in most of these borings, resting directly on the stone, in the hope that if the stone were merely a boulder some shattering or change of position would occur. Subsequent examination showed no such effects, though the diamond drill borings and the sinking revealed the fact that in only one case (and that very doubtful) could the stone located by the wash borings have been anything more than boulders, usually of moderate size, lying on the clay. The possibility of the stone located by the diamond drill borings being merely large boulders was guarded against by carrying each boring about 10 ft. into the rock and securing cores of the same for examination.

With the diamond drill borings as data, the caisson, masonry and coffer-dam of the north pier were designed of such heights as corresponded to a final depth of the cutting edge of 100 ft. below mean high water, or 5 ft. above the deepest known rock. The clay was of such hardness and of so great a depth that entirely suitable foundations for any bridge, except perhaps a suspension bridge, would have been secured by sinking the cutting edge only a few feet into it and not trying to reach the rock. The slightest settlement would affect the verticality of the high tower, however, and as in this case the rock could be reached by the pneumatic process at what was proportionally only a very small addition to the cost of the bridge, the only wise and conservative treatment was to carry the foundations to the rock. In case the rock had been much deeper, it is very probable the clay would have been used as a foundation. It was fully equal for this purpose to the clays on which are founded the truss bridges over the Missouri River at Rulo and Bismarck and the long span cantiliver bridge over the Mississippi River at Memphis.

When the caisson of the north pier was landed on the river bottom its cutting edge was about 49 ft. below mean high water. The ordinary fall of the tide was nearly 5 ft. The river bottom was covered by about a foot of very offensive sewer mud, and below this to a depth of 63 ft. to 72 ft. (average about 68½ ft.), extended a bed of sand, gravel and cobbles, with some boulders. Below this lay a bed of hard, dry stratified clay extending to the rock, the highest point of which was found at a depth of about 84½ feet, and the lowest at 107.5 ft. The average depth of the original rock surface within the whole area of the caisson was 96.5 ft. The maximum depth of 110 ft. which has been published several times is incorrect.

The cutting edge was stopped at a depth of 95 ft. (5 ft. higher than originally intended), 46 per cent. of it being then within a few inches of the excavated rock surface and the remainder an average of 7 ft. and an extreme height of 11 ft. above the original rock. The excavated rock surface covered 42 per cent. of the area of the caisson. The mean depth of the final rock surface over the whole area of the caisson is 98.3 ft. below mean high water.

The comparatively small amount of work done at the greatest depths is shown by the amount of excavation being only about 2 cu. yds. below the depth of 106 ft., 21 cu. yds. below 104 ft., 77 cu. yds. below 102 ft. and 183 cu. yds. below 100 ft. The size of the caisson was 63 ft. x 79 ft., giving a volume per foot depth for its whole area of 184 cu. yds. The deeper parts were left uncovered as short a time as possible, about 40 cu. yds. of the excavation being done after the concreting was begun. The extreme depth of 107.5 ft. existed for less than an hour, concrete being placed on the rock within a few minutes after it was satisfactorily cleaned.

The indicated air pressure exceeded that corresponding to the depth of cutting edge by several pounds (generally from 3 to 6 lbs.) from the beginning down to a depth of about 75 ft., or until all parts of the edge were well within the clay. From this depth to about 90 ft. the two pressures corresponded quite closely, sometimes one and sometimes the other being slightly larger. Below 90 ft., as already mentioned, the indicated pressure was much smaller than that corresponding to the depth of water.

Almost from the beginning the excavation in the middle of the caisson was carried to depths of 6 ft. to 8 ft. below the edge, and this accounts for the excessive pressures carried in the permeable materials above the clay. The advantage of doing the work in this way was that all the excavation could be done below the horizontal struts in the working chamber without interference from them and that the material could be excavated to a large degree from a face. This method could be used only in a broad caisson, as in a narrow one the slopes needed next the edge would leave very little space available for deepening the excavation in the middle.

The sinkages were made intermittently, usually from 3 ft. to 6 ft. in one or two days, after many days spent in preparatory excavation. The maxima were 4 ft. in one day, and at another time 5.9 ft. in two days. Slopes were carried around the edge as long as possible until just before the sinkage.

The question of danger of course arises in carrying excavations below the cutting edge. So long as the pressure maintained is as great as that corresponding to the edge no possible danger can arise from this cause, as the water, even in case of an inburst, will not rise above the level of the edge. Even a somewhat less pressure im-

plies no danger, as it is a common occurrence to allow the water to rise 3 ft. in caisson chambers during a sinkage, the men taking refuge on the beams.

When the excavation is carried 11 ft. vertically below the cutting edge, however, to a depth of 106 ft. below mean high water, and the pressure maintained is not more than 36 lbs. per sq. in., some degree of danger may be thought to have been incurred. The depth corresponding to a pressure of 36 lbs. is 81 ft., or 14 ft. less than the depth of the edge and 25 ft. less than the extreme depth of the vertical clay face. The pressure corresponding to the depth of cutting edge is 42.2 lbs., and that corresponding to the extreme depth of 106 ft. is 47 lbs.

From the information furnished by the borings it was decided that it would be conservative to take advantage of the bed of clay to stop the cutting edge at a height of at least 5 ft. above the deepest rock. This allowed a saving of 5 ft. in both masonry and coffer-dam and a large saving in rock excavation, these savings largely outbalancing the extra cost of the concrete needed to refill the excavation below the cutting edge. As actually built, the edge was stopped 5 ft. higher than intended, or at 95 ft. instead of 100 ft. depth. This resulted in a great saving of time, and also, as the work below a depth of 96 ft. was paid for by the cubic yard, in a further saving of cost to both the city and the contractor. The only change in the construction required by the less depth was the omission of 5 ft. from the coffer-dam and from the masonry below low water, and a considerable addition to the clay excavation and concrete refilling between the elevation of the cutting edge and the rock.

For the south half of the caisson the cutting edge has between it and the rock only a few inches of concrete, while for the north half it has an average intervening depth of 7 ft. and a maximum of 11 ft. This concrete will have an excess pressure from the completed bridge of only about 5 tons per sq. ft., while it might safely, in this location, bear 15 tons. The size of the pier was governed by the lateral dimensions of the tower leg instead of by unit working pressures. The compression which may occur in the extra depth of concrete under the north edge is inappreciable and entirely negligible. The concrete is receiving its load very gradually, as it was placed in 1898, and its full load will not have been reached for at least a year or two to come.

The clay was so impervious that the pressure in the working chamber could easily have been raised to the 47 lbs. per sq. in., corresponding to the maximum depth of 106 ft., or even much higher. The pay and the length of shift of the pressure men were fixed by the depth, and not by the pressure, so carrying a lower pressure than that corresponding to the full depth was of no direct advantage to the contractor, except, perhaps, an inappreciable saving in the cost of air compression. The only reason for using an air pressure less than the depth was a desire to lessen the chances of caisson disease among the men. Experience has shown that the disease is not very prevalent at depths less than 80 ft., corresponding (in fresh water) to pressures less than about 35 lbs. Advantage was therefore taken of the imperviousness of the clay to lower the pressure to about this point. There is no reason to suppose that it could not have been safely lowered much more, but with the unusually short hours of the men there was no object in doing so—besides, a limit must always be placed on such experiments. The height of the water inside the coffer-dam was also an element in determining the minimum air pressure. The constant and certain danger to the men from high pressures was prevented and a risk taken in exchange which was less, everything considered, than those usually taken in open excavations.

The only risk possible was in a sudden caving of the vertical bank and an inrush of water. As a matter of fact, the methods and care used obviated practically all risks. As before remarked, slopes were carried around the edge as long as possible and the clay dressed to a vertical face only a comparatively short time before sinking or before concreting. Planks and braces were kept on hand and used in a few places where it seemed advisable. A close watch was kept, and the air pressure could have been increased quickly if necessary. The characteristics of the clay were well known from work at higher levels and in the south pier. In that pier the edge was also 11 ft. above the lowest rock, but the average distance was much less than in the north pier. The maximum pressure carried was 31 lbs., about 5 lbs. less than

that corresponding to the depth of cutting edge and 10 lbs. less than that corresponding to the deepest rock.

The clay was very peculiar in its appearance, and quite unusual. It was very uniform and markedly stratified, resembling at a few feet distance a strongly laminated gneiss. It was, in fact, supposed to be a decomposed gneiss rock, until some small boulders were encountered in it. Its junction with the bed rock was plainly marked, only an inch or two of harder material separating them. The clay was free from sand, quite dry, and would absorb very little water, though by continued working it would become greasy and putty-like. It was so hard that it was found economical to excavate a great deal of it by blasting with dynamite, though it was not impracticable to excavate it by pick and bar. Vertical faces were soon affected by exposure to the air, pieces varying in size from a pail to a barrel detaching themselves slowly. This was easily prevented, where necessary, by planks.

The quality of the clay, its soundness—the stratification showing that it had not been disturbed since its original deposition—and its great thickness would have justified risks much greater than any taken. The minimum thickness of clay above the edge was 23 ft., and this was overlaid by a minimum thickness of 36 ft. of sand and excavated materials. No water was ever found leaking down from between the outside surface of the caisson and the clay.

In sand it is impracticable to do any work cheaply at a lower depth than the cutting edge, as the water is very sensitive to changes of pressure, and while in sand it is not possible the raise the pressure very much above that corresponding to the edge. When concreting on a sand foundation, it is often necessary to raise the pressure as high as may be in order to drive the water down in the sand and secure a dry bottom for the concrete. This was necessary in most of the sand foundations of the Cairo Bridge, the excess pressure being there usually 2 or 3 and in one case 5 lbs.

In clay, on the other hand, some work always has to be done below the edge. No sinkage can be made until the clay has been excavated vertically for the full depth of the proposed settlement, and this is done without increasing the air pressure. In one of the piers of the Rulo Bridge a test well was sunk through clay 17 ft. below the edge without any increase in the pressure. A 4-ft. vein of gravel was then struck, when the pressure had to be at once increased 8 to 10 lbs. When the well was refilled the pressure was lowered to its former amount. At the Memphis Bridge tests wells were sunk in each of the five pneumatic piers from 2 to 15 ft. below the edge in clay without any corresponding increases in pressure.

While working with pressures less than the depth is unusual in bridge piers, it is quite common in tunnels built with compressed air, where much reliance is often placed on the imperviousness and strength of the overlying materials and the compressed air is used largely as a safeguard and aid. The distinction between tunnels and bridge piers in this respect is that in the former no intentional connection exists between the tunnel and the water of river, while in the case of the latter the process of sinking necessarily makes a connection, more or less closed by shifting materials, between the working chamber and the river.

It is seen from the facts given that while work was done at a great depth in the New East River Bridge piers, they cannot be classed among structures where high pressures were used.

The most familiar example of high pressures is the St. Louis Bridge, where the sinking was through sand to rock. The east pier, when landed on rock, had its cutting edge immersed 93.2 ft., corresponding to over 40 lbs. per sq. in. The last 34 ft. was sunk in 27 days, or at an average rate of 15 ins. per day. Filling of the chamber with concrete was begun seven days later and discontinued after 38 days, when the immersion had reached a depth of 111.75 ft. The concreting was resumed after an intermission of 28 days, the river having fallen to an immersion of 107½ ft., and was completed 16 days later. The concreting of chamber lasted 53 working days (in two disconnected periods), and was done in pressures of 45 lbs. to 50 lbs., corresponding to theoretical immersions of about 104 ft. to 115 ft.

The only other deep sinking at the St. Louis Bridge was the sinking of the east abutment. When its cutting edge was 14.9 ft. above rock, with an immersion of 97.3 ft., the pressure carried was 43 lbs. Nine days later, with its edge 10.1 ft. above rock, an immersion of 101.1 ft. and

a pressure of 46 lbs., the work was stopped by a tornado. After an interval of eight days, the sinking was resumed and rock was reached twelve days later. When landed on the rock the edge was immersed 109.7 ft. and the pressure was 49 lbs. Two days later the placing of concrete under the edge and girders was begun and completed in 17 days. The remainder of the chamber was then pumped full of sand and water.

The most notable and successful instance among bridge foundations of long protracted continuous work under heavy pressures is the sinking of the two river piers of the Memphis Bridge, though but little attention seems to have been drawn to it. This work was done by day's labor under the direction of Mr. Alfred Noble as Resident Engineer. The piers are on clay foundations, and were sunk through sand and a few feet into the clay. In Pier II. the immersion of edge was for 11 days from 100 ft. to 104 ft., with indicated pressures of 41 lbs. to 43 lbs. and calculated pressures of 43 lbs. to 45 lbs. At a later period the immersion was from 93 ft. to 104 ft. for 50 days, the indicated pressures being 40½ lbs. to 44½ lbs. and the calculated 40½ lbs. to 45 lbs. In Pier III. the immersion was for 21 days from 90 ft. to 105 ft., with indicated pressures of 37 lbs. to 44½ lbs. and calculated pressures of 39 lbs. to 45½ lbs. For 75 days at a later time the immersion was 94 ft. to 106.4 ft., with the indicated and calculated pressures respectively 40 lbs. to 47 lbs. and 41 lbs. to 46 lbs.

An interesting observation of temperatures was made at the south Brooklyn pier of the New East River Bridge. This was done in the middle of June, while concreting the working chamber, with the air pressure 31 lbs per sq. in. The air lock was located about 20 ft. above the cutting edge at the foot of a deep damp 6-ft. shaft, and communicated alternately with this shaft and with the working chamber. The temperature of the lock just after "bringing it in" was + 95° F., and just after "taking it out" + 67°; the general temperature of the working chamber was by observation + 81°. Air was being delivered to the chamber at this time through two pipes, the regular pipe carrying cooled air and a smaller pipe carrying air which had not been cooled. The temperature at the exit of the cold air pipe was + 77° and at the hot air pipe + 90°. The time of bringing in the lock was probably about 3 mins. and of taking it out about 5 mins. The observation is unfortunately incomplete in not including these times and the general temperatures at the foot of the shaft and in the external air.

The air was cooled by passing it through a collection of 1-in. gas pipes (aggregating about 500 ft. in length) immersed in the river, and not by spraying. The same method had been used at Cairo, Memphis and elsewhere. The question of cooling the air for the north pier was unimportant, as the chamber of this pier was concreted in November.

The great immunity from caisson disease of the pressure men employed at great depths on the Brooklyn piers was due to three causes—to the pressure used being much less than that corresponding to the depth; to the length of shift being unusually short even for the full depth and still more so for the actual pressure, and to the use of an elevator in raising the men to the surface.

The deepest work was done with the edge at a depth of 95 feet. below mean high water and with the lowest rock under the edge at a depth of 106 ft. The pressure actually used, however, corresponded to a depth of only about 83 ft. (of fresh water). The corresponding hours worked were 1½ hours per 24 hours, divided into two shifts of ¾ hours each, with an interval of 4½ hours to 6 hours between shifts. This schedule applied to all work below 90 ft. depth, the hours for depths of 80 ft. to 90 ft. being two shifts of 1 hour each, with 4 hours rest between.

The schedules at the Memphis and Bellefontaine bridges were usually as follows:

80 ft. to 90 ft. depth, two shifts of 2 hours each; below 90 ft. depth, three shifts of 1 hour each. At the Kulo Bridge two shifts of 1½ hours each, were used between 80 ft. and 90 ft. The schedule at the Cairo Bridge was generally two shifts of 2 hours each for depths below 80 ft. (80-95), with 10 hours rest between; the shifts were in some cases reduced to 1½ hours each. The inspectors of concreting in the chamber of the north Brooklyn pier (all young engineers) worked two shifts of 1 hour each, or longer than the pressure men; and the writer and some others at times spent an aggregate of three or four hours per day in the pressure, taking extra shifts. The solicitude of the pressure men

for our health was touching but unconvincing, as most of them had worked on the Western bridges mentioned.

The use of an elevator for the men has been spoken of as a great safeguard against caisson disease. It is probably one of the most important in deep work, personal experience having shown that a climb up a ladder in a damp 3-ft. shaft, sometimes a hundred feet or more in depth, just after leaving the pressure, is a more exhausting task than the work in the air chamber. The climb is probably less enervating when made in compressed air, with the lock at the top of shaft, but for many reasons the bottom lock seems usually preferable. The use of elevators is not important when the depths are less than about 80 ft. Their use in connection with deep work should not be regarded as an extra expense, as the more effective work of the men when no long climb is anticipated will probably more than counterbalance their cost. Cooling of the air is very important in summer and in hot climates.

The habits of pressure men have a great deal to do with the prevalence of caisson disease. The high pay, short hours of work and period of idleness between shifts (generally not long enough to allow of going far from the work) all conduce toward the spending of much of the idle time in saloons, and to too much drinking and too little sleep. A "sand-hog" ball is generally followed by a greater prevalence of "bends" among the men.

An elevator was used at the east abutment of the St. Louis Bridge, and one was also used at both the Memphis and Bellefontaine bridges. At the Brooklyn piers of the New East River Bridge the elevator shaft was 6 ft. in diameter and the inside diameter of the elevator itself was 5.4 ft. The elevator would hold 18 large men, estimated at the time to average 170 lbs. each, making an average load per sq. ft. of its floor of about 134 lbs. The 6-ft. diameter lock would hold 20 men and allow the door to open inward. The men were in both cases very tightly packed.

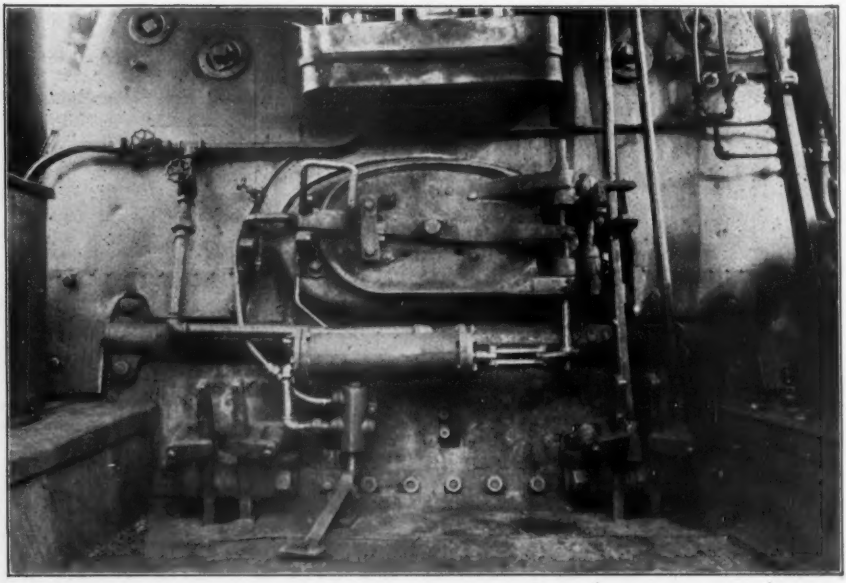
Much more might be written about the Brooklyn piers, but this is intended as a description of some special points only. The piers were built by the Degnon-McLean Construction Co., and the success attending the difficult pneumatic work was due principally to the good judgment and untiring watchfulness of J. E. Taber, their foreman in general charge of the sinking. —Edwin Duryea, Jr., in *Engineering News.*

A Pneumatic Fire-Door Opener.

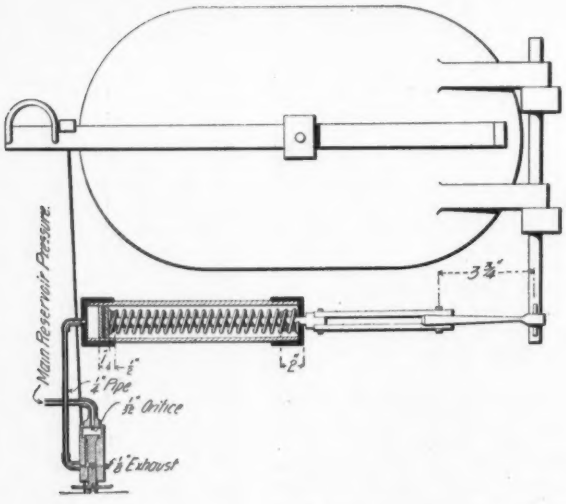
Mr. F. L. Brewer, an engineman on the Rock Island, has invented a device for opening and closing the fire-door of a locomotive. The only action required by the fireman is to press his foot on a pedal when he wishes the door to open and remove the pressure to allow it to close.

As will be seen by the ilustrations the apparatus is simple and of few parts. A cast-iron cylinder 2½ in. inside diameter and 14 in. long is bolted to the boiler horizontally just beneath the fire-door by two brackets which are an integral part of the casting. The drawing shows the original design, having the two heads threaded on the cylinder; this has been modified as shown in the engraving from the photograph, flanges being provided and heads bolted on. The piston is of steel, having two ¼-in cast-iron packing rings. The rod, which is ¾ in. in diameter, is enlarged at its outer end and shouldered into a crosshead, to which is attached a toggle-joint, connecting with a 3¾-in. crank, keyed to the door-hinge shaft. The shaft is keyed to the door-half of the upper hinge and has a set-screw through the lower one, insuring a rigid attachment.

The valve is simple in form and seats by gravity. Above the valve is a small chamber which is in pipe connection with the main reservoir; the air enters this chamber through an orifice 1-32 in. in diameter. The stem of the valve extends down through the casing, projecting ¼ in. or more below. The inner end of the operating pedal is directly beneath this stem and a depression of ½ in. at the outer end raises the valve clear of the seat, permitting the air to pass down through the small hole parallel to the valve stem and just to the left of it, and out through the pipe connection to the cylinder, which it enters through a ⅛-in. orifice. The piston has a 6-in. stroke which is sufficient to throw the door wide open. The air pressure acts against a flat-steel helical spring which operates to close the door the moment the air is released. The exhaust is through the same orifice in the cylinder that admits the air and the throttling ac-



BREWER'S PNEUMATIC FIRE-DOOR OPENER.



PNEUMATIC FIRE-DOOR OPENER—SECTIONAL VIEW.

tion of this opening provides a cushion for the spring pressure to act against, preventing the door from slamming. The exhaust reaches the atmosphere by passing around the valve stem through a ⅛-in. groove turned in the stem and thence through a ⅛-in. hole drilled in the casing.

Just back of the valve casing, with its lower end resting on the pedal, is a small steel rod held against the boiler head by suitable guides. Its upper end is in contact with a small latch which holds the door closed. This latch is raised simultaneously with the admission of the air. It is hinged to the boiler head and is cut under at its outer end so that when the door swings shut this small latch is raised and drops into place over the door latch.

With a 1-32-in. admission port the minimum pressure under which the device will work rapidly and easily is 60 lbs. With a lower pressure than this the action is too slow to be satisfactory. This can, of course, be regulated by varying the size of the admission orifice.

The device is in use on two Rock Island passenger engines, Nos. 1,301 and 1,303, in the fastest service on the road, and on No. 1,454, a wide fire-box, 10-wheel freight which is the largest engine on the road. The mechanical department of the Rock Island has been very carefully watching the results from the use of the door opener and recently asked the firemen on the engines equipped with the device for an expression of opinion as to its working, and whether or not it would effect a saving of fuel, lengthen the life of the fire-box, and cause a reduction of leaky flues. The replies were without exception very favorable. It was stated in every case that besides working perfectly, the fireman is able to put in a fire in about one-half the time required by the old method. These opinions have been substantiated by the traveling engineer and by Master Mechanic Stocks. The reports were also unanimous in the opinion that there was a saving in fuel, although no tests have been conducted to determine to what extent this is true. Other points mentioned were, that the engines steamed more freely, the black smoke is reduced, and the use of a second fireman on large engines would be rendered unnecessary. Mr. Brewer has applied for a patent on the device.—*Railroad Gazette.*

Compressed Air for Mining from Electric Power.

This paper records some actual results obtained using a 10x18-inch duplex, single stage, belt driven compressor, the area of the outlet ports being 9 square inches on each end of each cylinder, the port area being reduced to 6¼ square inches where it enters the main pipe, a disadvantage, but in this particular compressor, unavoidable. The water jacket covered only three-fourths of the surface of cylinder, one-quarter being taken up by the air ports, another defect in construction. The working pressure varies from seventy-five pounds to eighty-five pounds, blowing off at eighty-five pounds. The compressor runs fifty-nine revolutions per minute, the valves being the ordinary poppet type.

In driving this machine a 30 H. P. General Electric induction motor is used, speed 900 R. P. M., voltage 550, the current being transformed from 10,000 volts in a separate building about 250 feet from compressor house, and measured on the low tension side by an integrating Schallenberger watt meter, 746 watts being considered the equivalent of a mechanical horse power. The current is transmitted from the Standard Electric Co.'s plant, near Jackson, Amador Co., Cal., a distance of 8 miles. The price per H. P. meter measure is $6.50 per month, which is the maximum rate, and which is reduced somewhat according to the amount of H. P. contracted for above a certain amount.

The compressor pumps directly to a small receiver—in this case too small by 500 cubic feet—the total storage being only about 100 cubic feet, allowing altogether too sudden flutuations in air pressure and not enough to carry all the air compressed during the small periods of idleness, of power drills and hoisting engine, without blowing off air.

This brings up an important point in compressor practice, that blowing off air is a large item of expense, is wasteful, and an apparent negligence of proper installation, but for some unaccountable reason is generally considered unavoidable in a compressor plant. Have plenty of storage and the right size compressor, and compressed air will be economical and not expensive, as is the opinion of most users of air compressors.

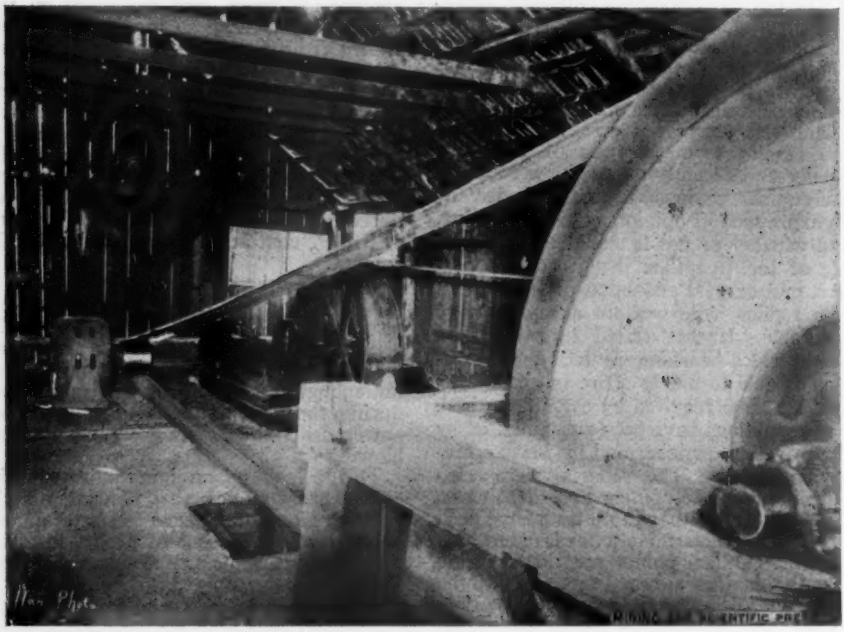
In this case the blow-off of the receiver is so arranged that it empties into the steam boiler, where it is reheated and used in hoisting engine, passing in just above the water line, through front end of boiler, as shown in the illustration herewith. When the power drills are not operating the lever is raised and all the air passes to the boiler for hoisting purposes. Attention is called to the sketch showing the general arrangement of plant; where possible to do so elbows are avoided and long sweeps are used, by bending the pipe —these bends being made very carefully to avoid any crushing of side of pipe.

Where pressure in receiver rises above seventy-five pounds it overcomes the weight and escapes through the 3-inch check valve; it passes out the side opening of 2½ inch tee, through which passes the stem shown in dotted lines and passes to steam boiler. A check valve shown in the photograph prevents the steam from backing out of boiler when air is below steam pressure—this arrangement makes the blow-off on steam boiler the blow-off of compressor.

Air is used cold in the power drills, but in the engine it is reheated to about the temperature of steam at forty pounds pressure.

The average consumption of fuel used in combination with electricity for sixty days was:

Twenty H. P. per day at a cost of	$270.00
Wood burned in mean time, 37½ cords at $6	225.00
Total cost for power	$495.00
Under former conditions it required:	
Two cords of pine wood per day 120 cords, at $6	$720.00
Water power for compressor (very favorable conditions) two months	350.00
Total by wood and water	$1,070.00
Tons of rock broken by power drills and hoisted 550 feet	2,667
Tons of water hoisted 600 feet	3,600



30 H. P. MOTOR AND 10X18-INCH DUPLEX COMPRESSOR, SPRING HILL MINE, AMADOR, CAL.

Under the present conditions should the power drills and hoisting engine be idle all at once for more than one minute the air blows off, due to lack of storage, which as soon as rectified should make a difference of at least ten cords of wood. Electricity at $6.50 per H. P. month is about 21 cents per horse power for twenty-four hours, consuming, as this plant does, about 20 H. P. per day, means $4.50 per day to produce enough air at eighty pounds pressure to operate two power drills (3¼-inch cylinders) and leave a surplus for hoisting engine sufficient to save the use of over one and one-quarter cord of wood per day. Had all the air pumped to eighty pounds been conserved by ample storage the use of less than one-half cord of wood would have been sufficient for all reheating purposes and supplying steam at times when air pressure was low.

Below is given the fuel cost of power by oil, where it will be noted that the cost per horse power for twenty-four hours is 38 cents; by electricity for twenty-four hours, 21 cents, at $6.50 per H. P. month: by wood, at $6 per cord, 53½ cents, as near as can be estimated. Very few mining

AIR PIPE FROM COMPRESSOR ENTERING BOILER, SPRING HILL MINE.

plants are equipped with as perfect a boiler plant as was the boiler plant used in gaining these results by oil:

FUEL COST OF POWER BY OIL.

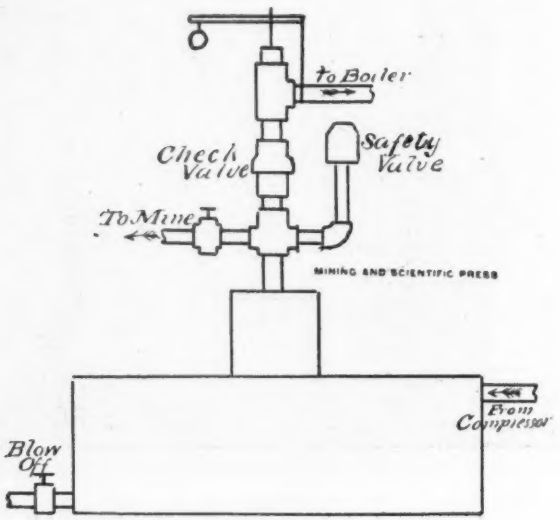
One barrel 16° oil=.....	330 pounds
At $1.50 per barrel delivered=....	$0.00455 per pound.
Heat units per pound=.....	18,000
Heat units per pound of steam at 100 pounds, with feed water at 50° F. =.....	1,167
Theoretical evaporation pounds of water per pound of oil =.....	15.4
Actual evaporation, assuming 65% efficiency for boilers, including steam required for vaporization, pumps, etc. =.....	10.00
Allowing 35 pounds of steam per H. P. hour on engine, including feed pumps, etc., pounds ot oil per H. P. hour, will =.....	3.5
Fuel cost per H. P. hour=$0.00455 ×3.5 pounds =.....	$0.0159
Fuel cost per H. P. hour for 24 hours =.....	$0.38
Fuel cost per H. P. hour per month =.....	$11.40
Fuel cost per H. P. hour per year =.....	$136.80

The cost of reheating air in a steam boiler is very trivial; for every twenty-four pounds of good coal used in reheating compressed air at about eighty pounds pressure an additional horse power for twenty-four hours can be secured, whereas it requires under good conditions from 96 to 120 pounds of good coal to get one horse power for twenty-four hours from steam.

Two cords of good pine wood is generally taken as the equivalent of one ton of good coal, and fuel oil at $1.12½ per barrel is about the equivalent in heat production under a steam boiler to good coal at $5 per ton. The efficiency of an electric motor is from 85% to something above 90%, whereas from use of wood, coal or oil there is a tremendous loss of heat, in radiation and in heat going up the stack, so that probably 15% would represent about the efficiency of a steam plant.

For the guidance of those who may contemplate the use of air the following general directions will prove most satisfactory from a power standpoint as well as maintenance:

Get a compressor that does not require to be run above 200 feet of piston speed per minute.



Use a two-stage tandem straight-line machine when possible.

Have heavy flywheels.

Avoid countershafting, by using large flywheel.

Have the stroke at least double the diameter of cylinder.

Have long stroke machines rather than short ones.

Have storage that will require the compressor at least one-half hour to fill.

Have the compressor equipped with an unloader.

And above all, have a compressor as nearly equal to the work to be done as possible. The larger the compressor the more dead work, in friction. These may seem commonplace suggestions to a great many, but are the elements that, either considered or neglected, go to make a successful and satisfactory plant or a very unsuccessful and unsatisfactory one. As much intelligence and experience is required in the installation of a compressed air plant as in electrical or other power plant installations.—John B. Tregloan in *Mining and Scientific Press.*

Electrically Operated Air Compressors.

One of the remarkable developments in the recent history of engineering progress is the constantly increasing use of compressed air as a medium of performing many and varied industrial operations.

Pneumatic tools and other appliances for the utilization of compressed air have been introduced into one field after another with gratifying results and the advantage of using compressed air for a wide variety of other purposes is now fully recognized.

The present general use of electricity renders it advantageous in many instances to operate air compressors with electric motors. The convenience and economy of this method is apparent when it is remembered that an electrically driven compressor can be operated from any lighting, power or railway circuit that may be available.

To meet the constantly increasing demand for an electrically-driven, simple, compact air compressing unit, the Christensen Engineering Company, Milwaukee, are manufacturing a complete line of motor-driven compressors. The smaller sizes are made for portable as well as stationary service.

The type "M" motor-driven air compressor, illustrated herewith, is for stationary continuous service and is built in capacities from 50 to 1,000 cubic feet of free air per minute.

The electric motor and the compressor have been designed to form a compact, self-contained unit. The air is compressed in the cylinder, shown on the left, by a double-acting piston, which is operated by means of a connecting rod and steel crank shaft. The latter is mounted in bearings located within the frame of the machine. This shaft carries on the motor end a helical gear, which is driven by a pinion on the armature shaft of the motor. The entire machine is mounted on a substantial cast iron base.

Both the cylinder and the valve heads are water jacketed throughout. The clearance spaces have been reduced to the lowest practicable limit, thereby correspondingly increasing the economy.

The suction and discharge valves are arranged in cast iron heads bolted directly to the cylinder. They consist of seamless, cold-drawn steel cups, so arranged that each is removable independent of the other. No springs are used with these valves. They are operated by the compressed air itself and are reseated by gravity. The peculiar construction of these valves renders a small lift possible, hence the noise from their operation is reduced to a minimum. The suction and discharge valves are identical and interchangeable. Only one connection is necessary when piping from the compressing cylinder to the reservoir.

The piston is provided with an improved form of packing rings. The piston rod is of steel, carefully ground true on dead centres. The rod passes through a self-adjusting metallic packing box.

The connecting rod is composed of steel and is arranged to receive oil for lubricating the crank pin, wrist pin and piston. The crosshead is provided with adjustable shoes of extra large area and with an accurately ground hardened tool steel wrist pin which fits into a phosphor bronze bearing in the rod.

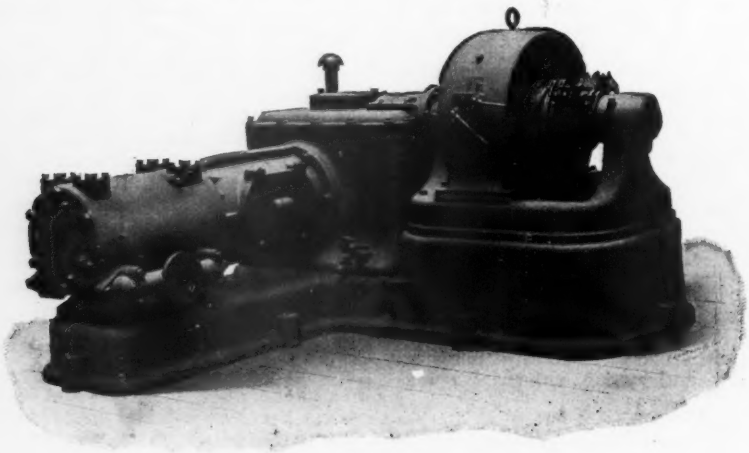
The crank shaft is composed of a high grade steel, and is provided with extra large bearings, thus avoiding the frequent adjustment of the bearing boxes which is usually necessary with bearings of or-

dinary size. The shaft is carefully balanced and accurately turned true to receive the connecting rod.

The crank shaft is extended at the motor end to carry the gear, which is driven by a pinion on the armature shaft of the motor. The gear and pinion are of the helical herring-bone type, with teeth cut by special machinery in the most perfect manner, thereby reducing the noise.

The gear case and the crank chamber are connected and form an enclosure which is partly filled with oil, with which all the working parts are automatically and continuously lubricated, including the air cylinder. The latter is connected with the oil chamber, so that the proper quantity of oil for lubricating the surface between the cylinder and the piston is automatically supplied and no sight feed lubricator is required. The motion of the crank shaft in the oil causes continuous lubrication of the main bearings, the crank pin bearing of the connecting rod, the cross-head guide, the piston rod, the wrist pin in the cross-head and the piston. Oil is also supplied automatically to the bearings at the pinion end of the motor. The gear and pinion operate continuously in the oil bath. The machine will remain lubricated as long as the oil is kept up to a level determined by a filling plug on the side of the crank chamber. Experience has shown that, after being supplied with oil, the compressor runs for several weeks before replenishing is necessary.

Either an alternating or a continuous current motor may be used. The illustrations herewith show the continuous current multipolar type. The lower frame of the motor is of cast iron and the field is composed of low carbon cast steel with detachable steel pole pieces. The motors are series wound and are started and stopped without using resistance of any kind. The armature is of the latest ventilated type, built up of discs of soft steel and slotted to receive the winding. Machine formed armature coils are used; the insulation and other materials are of the highest grade obtainable. The commutator is built up of hard-drawn bars of the best lake copper, insulated from each other by segments of mica. The armature shaft revolves in extra long bronze bearings with ring oiling arrangement. The bearings are so designed that it is impossible for oil to get into the armature.



TYPE "M" CHRISTENSEN MOTOR-DRIVEN COMPRESSOR.

The brush holder is of the simplest possible construction. It is provided with an instantaneous tension adjuster, arranged so that the tension can be increased while the motor is running.

The design of the motor and compressor is such that every part is easily and quickly accessible.

By unscrewing a few bolts the armature

and the field coils can be removed or exchanged. The gear, pinion, valves or cylinder heads may also be removed without disturbing any other parts.

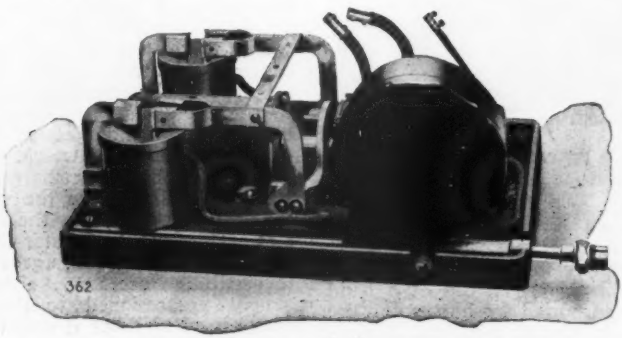
Access to the cross-head and wrist pin is obtained by doors conveniently arranged on the side of the slide frame. The crank chamber is constructed so that it is completely closed, but the upper part may be quickly removed, giving free access to all the working parts, while a smaller hand-hole covering is provided and may be easily removed for inspection of the interior.

An automatic governor starts and stops the motor at the desired minimum and maximum air pressures. This is a very simple piece of apparatus, consisting of an ordinary pressure gauge mechanism with a special hand which, upon coming in contact with a conducting stud at the position of minimum pressure, allows current to flow through a magnet coil. This coil operates a plunger, to which the contact pieces for the motor circuit are attached, thereby closing the circuit and starting the motor.

As soon as the pressure reaches the desired maximum the hand strikes another stud and current passes through a second solenoid magnet, thereby pulling the plunger in the opposite direction and opening the motor circuit. By this mechanism it is possible to get a close margin between maximum and minimum pressures. This margin is readily adjusted by moving the contact studs.

A smaller compressor for stationary continuous service is built in capacities from 4 to 35 cubic feet of free air per minute.

These are known as type "L" and they are similar in design and construction to type "M," described above. The motor is mounted directly over the compressor instead of on the side. The compressor has two cylinders, which are water jacketed throughout. Each cylinder is provided with a single-acting plunger piston, which is operated by a connecting rod from a well-balanced steel crank shaft. The shaft is extended at one end to carry a helical gear, which is driven by a pinion on the armature shaft of the motor directly above. The base of the motor forms a cover for the compressor frame and the gears are also enclosed in a suitable casing. The interior of the compressor is, therefore, completely enclosed and protected from injury. This compressor is a modification of the type "H"; the water jacketing feature being added to make it suitable for continuous service.



GOVERNOR FOR TYPE "M" COMPRESSOR.

The suction and discharge valves are of seamless, cold-drawn steel. They are conveniently arranged in the cylinder back cover so that each is independent of the other and separately accessible.

The illustration of the type "L" herewith show the current type for use with air-brake equipments on electric cars. They are four-pole, series-wound motors, with two field coils, with cast steel frames.

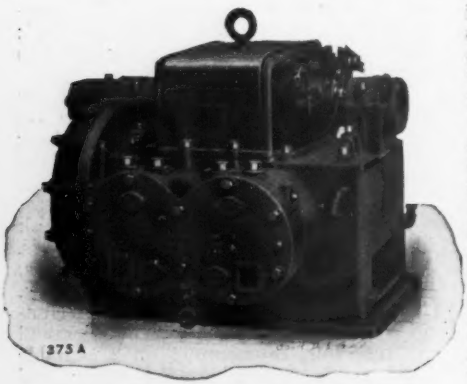
For portable service the type "H" compressor, with the automatic governor and air reservoir, is mounted on a suitable hand truck, which can be easily and quickly moved wherever necessary. This

portable outfit, known as type "I", finds a field of usefulness wherever pneumatic tools or other compressed air appliances are used and an expensive system of piping is not desirable. The compressor is taken to the work instead of transmitting

TYPE "I" PORTABLE COMPRESSOR.

the compressed air from a stationary compressor at a distance.

These compressors are frequently mounted on a wagon instead of a hand truck and transported by horses for use in drilling and bonding rails, etc., in electric railway or other work where electric power can be obtained. It is only necessary to make a connection to the trolley wire by a hook or pole for the purpose of obtaining power for the motor.



TYPE "L" CHRISTENSEN COMPRESSOR.

For this information and the illustrations shown we are indebted to the Christensen Engineering Co., Milwaukee.

Types of Foreign Air Compressors.

AIR-COMPRESSING PLANT BY SCHNEIDER & CIE., LE CREUSOT, FRANCE.

In fixing upon a type of compressor the Creusot engineers decided to adopt a form admitting of the immediate and fullest possible contact of the air with cooling water by direct injection of the latter into the compressing cylinder. Although they consider this method of cooling the most simple and the most economical for large productions, it has not (observed M. Burdy, head draughtsman at the Creusot works, to the Société de l'Industrie) succeeded, as hitherto applied, in preventing an appreciable elevation in temperature of the air during its compression. The useful effect of the injection depends upon the temperature and weight of the water injected during the compression, on the state of subdivision of the water and on the position occupied by the spraying nozzles. The weight of water to be injected per piston stroke, always greater than that theoretically necessary, should not be simply proportioned to the weight of compressed air; but it ought to increase with the speed of the compressors in a proportion which experimental investigations can alone determine. The air and water between which the exchange of heat is to be effected are two bad conductors, and in this particular case of heat exchange sufficient account has not yet been taken of one important factor, viz.: time.

In an ordinary compressor, making only about 60 revolutions per minute, the period of compression does not greatly exceed a quarter of a second, and it is during this very short space of time that the heat exchange between the air and water must be made. The shorter the time the greater must be the weight of water in excess, the degree of subdivision in this water, and consequently the multiplicity of points of contact; and, to avoid, in certain cases, an excessive weight of injection water, it was found well to restrict the duration of this injection to the

actual period of compression. A sufficient subdivision of the water escaping from injection nozzles is obtained in several ways. The trials made at the Creusot works, when the new compressing plant for the Blanzy Colliery was being gotten out, showed that the degree of subdivision might vary considerably for slight differences of construction and proportions of the nozzles; and in the arrangement adopted as the result of those trials the subdivision of the water is entirely effected by the shock of the water jets, which meet one another on escaping from a double ring of small orifices.

Fig. 1 of the accompanying illustrations gives a transverse section of the Blanzy Plant, showing the air and steam cylinders and also the boilers. The feed-pumps for injecting the cooling-down water are driven by a special engine, the speed of which can vary within large limits; but this arrangement, the only one which permits of properly regulating the volume delivered by the nozzles, is only applicable to large plants. The degree of subdivision in the water depends not only on the type of nozzle adopted, but also upon the excess of water pressure over that of the air. This 3,000 H. P. plant is divided into six 500-horse groups, each consisting of a horizontal Corliss steam engine, with high and low pressure cylinders and intermediate reheater, the pistons working on to the same shaft, and driving an air-compressor, with two cylinders arranged tandem-fashion behind the steam cylinders, and compressing in stages with intermediate cooling receiver. The compressors are provided with Corliss inlet and delivery valves, with water injection by three nozzles arranged on each cover, with water circulation round the jackets and with air receivers for intake and compression.

The air-pumps of the condensers, the feed-pumps of the boilers, the injection and circulation pumps of the compressors with the drain-pumps for the steam pipes and intermediate reheaters have been separated from the main engines and are driven in a group by a special motor, in order to ensure the uninterrupted working of the engines by freeing them from what constitutes a frequent cause of stop-

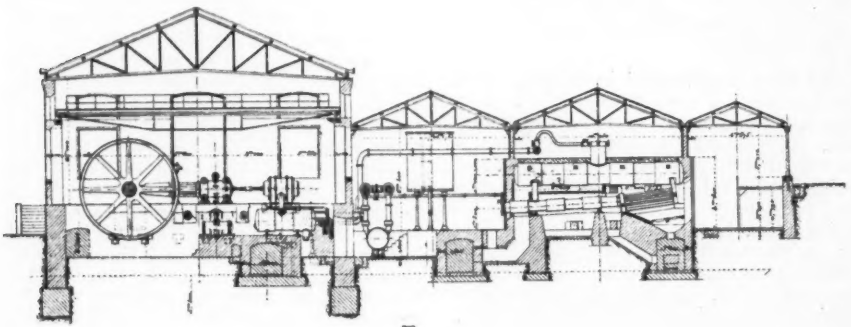


FIG. 1.

SECTION OF BLANZY AIR COMPRESSING PLANT.

page. Every precaution is taken for ensuring that the stoppage of any one pump of the auxiliary group, or even the complete stoppage of that group, shall not interfere with the working of the air-compressing engines; and the various pipes, especially the steam pipes, were designed to avoid a simultaneous stoppage of all the engines, whatever breakdown may occur.

The air drawn in is freed from its dust, moistened and cooled before entering the cylinders, by being made to pass through a special charcoal filter and a decantation chamber. The injection and circulation water for the compressors is freed from suspended impurities by large sponge filters; and these filters, together with the MacNicol boilers, the pipes and receiv-

ers—the whole plant, in fact—were made at the Creusot works. The following are the leading dimensions and particulars:

Diameter of small steam cylinders, 65 cm. = 26 in.

Diameter of large steam cylinders, 1m. = 40 in.

Diameter of large air cylinders, 90 cm. = 35 in.

Diameter of small air cylinders, 56 cm. = 22 in.

Common stroke, 1.25 m. = 4 ft.

Normal number of revolutions per minute, 60.

Pressure of compressed air, 6 kg. per sq. cm. = 85 lb. per sq. in.

Initial steam pressure on small pistons, 7 kg. per sq. cm. = 99 lb. per sq. in.

Boiler pressure, 8 kg. per sq. cm. = 113 lb. per sq. in.

The plant was started in August, 1892, and has worked ever since without stoppage and without giving rise to any incident. The obligation of starting the compressors directly they were erected and of avoiding any interruption in their working has prevented the carrying out of intended tests, but observations made during an uninterrupted period of 96 hours about a year after the plant was brought into operation, furnished information which is interesting because it bore upon the current working of the compressors that was then defective. This was due to insufficient vacuum in the condensers, the auxiliary engine working without expansion and one of the intermediate reheaters not having been brought into use; but, notwithstanding these disadvantages, the following satisfactory results were found to have been attained: Ratio between Ind. H. P. on the compressor pistons and the Ind. H. P. on the steam pistons, 0.843; ratio between the power stored up in the compressed-air receivers and the work given out on the steam pistons, 0.79, and volumetric yield of the compressors, 0.92.

CREUSOT 3-STAGE AIR-COMPRESSOR.

An improved type of compressor is that made by MM. Schneider et Cie, for compressing air to 50 atmospheres (735 lbs. per sq. in.) in three double-acting cylinders marked D, E and G on the accompanying plan—Fig. 2. The motor is a

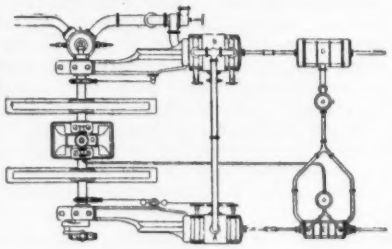


FIG. 2.—THREE STAGE COMPRESSOR FOR 735 LBS. PRESSURE.

horizontal Corliss compound condensing engine with two steam-jacketed cylinders, A and B, and an intermediate receiver. The speed, which is 72 revolutions per minute in normal working, may be made to vary from 54 to 90 revolutions. The low-pressure and intermediate air cylinders, D and E, are arranged in line with the steam cylinders, but the high-pressure compressing cylinder, G, is vertical, its piston being worked by a crank off the fly-wheel shaft. Between two successive cylinders there is an intermediate receiver I or J, in which the air is cooled by a stream of water, and there is also water circulation round the three cylinders, with injection into the first two, by means of a pump connected with the air-pump of the condenser.

The low-pressure cylinder, of which a vertical section and an end view are shown by Fig. 3, has two jackets, the

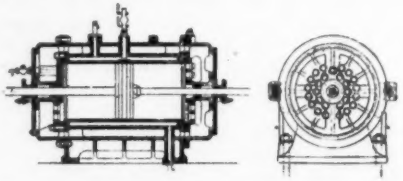


FIG. 3.—SECTION OF LOW PRESSURE CYLINDER OF COMPRESSOR SHOWN IN FIG. 2.

inner one serving for water circulation and the outer (extending also over the covers) constituting the air-receiver, while each cover contains the seats of 13 inlet and 13 delivery Corliss valves. The valves, of which details are also added,

Fig. 4, consist of flat discs of phosphor bronze, 6 cm. (2½ in.) in diameter and of about 1 mm. (say 1-16th in.) thick. Each disc is kept down upon its seat by a brass

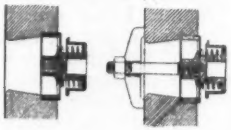


FIG. 4.—SECTION OF VALVES OF CYLINDER SHOWN IN FIG. 3.

spiral spring, made of flat bar, so elastic that it yields to the slightest pressure. By this arrangement the loss of load and re-entrance of air, unavoidable with self-acting valves, are almost entirely suppressed, and the great number of valves affords a large sectional area of opening for the air's passage, being at least 18 per cent. of the piston area both for inlet and delivery.

The two packing rings of the low-pressure piston are made of gun-metal, and the three rings each of the other pistons are of ebonite. The vertical position of the high-pressure air cylinder possesses certain advantages. Water collects in the lower portion of a horizontal cylinder, while the piston also presses on the same place, causing considerable wear and leading to the necessity of reboring; and the leakage of air due to the ovalization of the cylinder is a function of the difference in pressure on the two piston faces. For the low-pressure air-cylinder this difference is only 3.5 atmospheres (51 lbs. per sq. in); but it exceeds 40 atmospheres (588 lbs. per sq. in.) in the high-pressure cylinder. With a vertical position of the latter the water introduced with the air covers the whole surface of the piston and forms a tight joint, which opposes leakage, at any rate in one direction.

HANARTE AIR COMPRESSOR.

After many trials with dry compressors the engineer of the Mont-Cenis Tunnel, M. Sommeiller, adopted the hydraulic piston compressor for carrying out his great work, and devised a form called after him the Sommeiller, this consisting of two cylindrical vessels connected together by a horizontal cylinder, in which moves a piston entirely surrounded by water, this piston raising and lowering in the columns a body of water for drawing in and compressing the air. Tests at Mont-Cenis and at the Saint-Gothard showed that this appliance was capable of giving out as much as 95 per cent. of useful effect, provided the speed did not exceed 14 revolutions per minute, corresponding with a piston speed of about 2 ft. per second; but, if this was exceeded, the means for cooling became insufficient, and the speed communicated to the water by the compressing piston caused shocks, owing to which regular compression was not effected.

By giving a rational form to the compression columns M. Gustave Hanarte, Ingenieur Civil des Mines, of Mons, Belgium, has transformed this hydraulic-piston compressor, making it work at three times the speed, and increasing its useful effect by rendering more complete the means for cooling down the compressed air.

With reference to Fig. 5 of the accompanying illustrations, partly in vertical sec-

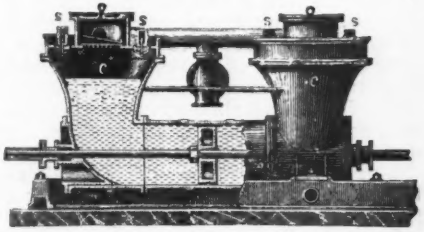


FIG. 5.—SECTIONAL VIEW OF HANARTE WATER COMPRESSOR.

tion and partly in elevation, the air is compressed by water volumes of increasing sectional area in the splayed-out columns, c c, which permit the water impelled by the piston to gradually slacken speed until it reaches the delivery valves. At each stroke a slight quantity of water is expelled with the air, and there enters by the inlet valves, s s, seated in the cover above, a corresponding quantity of cold water led up by a pipe.

The pressure, p, exerted on the piston, of area M, moving at a speed of v per second, produces a mechanical work, p M v, which is transmitted to the area n M, due to the splaying out, while being transformed into p n M $\frac{v}{n}$. Accordingly, the air and water reach the delivery valves at

a reduced speed equal to $\frac{v}{n}$, resulting from the ratio (n) which exists between the piston area and the upper sectional area of the splayed-out column. Thanks to this arrangement, shocks and a sudden starting of the water due to acquired speed are entirely avoided; and the compressor can run at a considerable speed, provided that the splaying-out be in accordance with a rigorously parabolic curve, which alone can permit the water to pass without disturbance from the speed v to that of $\frac{v}{n}$. For the same reasons the drawing in of the air is also favored by the descending body of water.

It is well known that, when air is compressed to the effective pressures of 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 atmospheres, if there be no cooling down, this air will attain the respective temperatures of 85, 130, 165, 195, 220, 242, 263, 281 and 298 degrees Centigrade; but, if this heat be abstracted as it is given out, the air compression will be effected, according to Mariotte's law, with a minimum of mechanical work and consequently a maximum of useful effect, which is obtained almost in its entirety by the parabolic columns of compression. In fact, the bodies of water which compress the air in rising, become renewed and extended, so as to take off the heat proportionately to the law according to which it is produced.

For large air-compressing plants the Hanarte compressor assumes the form shown by Fig. 6; and such compressors

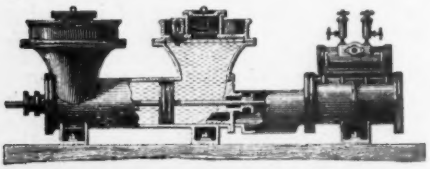


FIG. 6.—IMPROVED HANARTE WATER COMPRESSOR.

have been erected at a great many collieries in France and Belgium, while tests carried out on several of them have shown that this method of cooling the compressed air is so efficacious as to dispense with the use of water-sprayers, which, however, can be added if desired.

Indicator diagrams taken on the steam and air cylinders at the Dourges Colliery, in France, and that of the Bois-du-Luc, in Belgium, with a piston stroke of one metre (3 ft. 3⅜ in.), from 27 to 40 revolutions per minute, boiler pressures of 3 atmospheres (29 lbs. per sq. in.), and the same pressure of the compressed air, have shown that the mechanical yield of the compressor was 96.8 per cent. and the useful effect of the whole plant 87 per cent. Besides its use for mines, this compressor is also employed in public works, for producing a vacuum or for compressing gases; and in its application to the artificial production of ice or cold air with ammonia or carbonic anhydride, oil is substituted for water in the compression columns.

In addition to the advantages due to the splayed-out form given to the compression columns, the Hanarte air-compressor contains several improvements which contribute to its efficient working. The compression water encounters no obstacle in its movement, because all the spring-weighted valves are seated in the cover above, which valves move vertically with great regularity; the valve seats may be taken out without breaking a joint; and, lastly, the cylinder is independent of the columns, so that it can be renewed separately, while the bolt-holes are divided so correctly that a quarter turn may be given to the cylinder from time to time, so as to prevent its wearing oval.

BURCKHARDT & WEISS' AIR-COMPRESSOR.

These constructors, of Bale, Switzerland, have substituted for the automatic suction and delivery valves a slide-valve, worked by eccentric and sheave, as in the usual steam engine; but the air follows, in the ports, a path the reverse that of the steam, and the eccentric is keyed 90 degs. behind the crank.

If an ordinary slide-valve were employed the piston would, directly compression begins, be subjected to the whole pressure of the receiver, which would greatly increase the work of compression at the expense of the useful effect. The difficulty, however, is obviated by using a slide-valve of Meyer type with special passages for the delivery, leading to a single orifice at the back of the slide-valve. This orifice is closed by a retaining valve formed by a large plate, P—, see accom-

panying section Fig. 7, guided by the pin, Q, and kept down upon its seat by a spiral spring, only rising when the pressure on the compressing face of the piston exceeds that in the receiver.

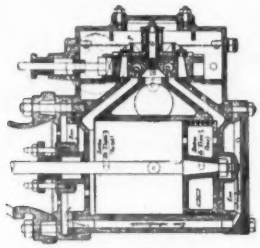


FIG. 7.—SECTION OF AIR-COMPRESSOR WITH MEYER SLIDE VALVE.

The influence of the dead space is largely overcome by the presence of a compensation passage, O O, entirely formed in the body of the slide-valve during the operation of casting, thus putting the two sides of the cylinder in communication when the slide-valve is at its mid position and the crank on the centre point. Consequently, after each stroke, the compressed air contained in the dead space passes behind the piston and is compressed with that which has just been drawn in, while on the opposite side the tension of the air falls to that of atmospheric pressure from the beginning of the stroke, and the air may be drawn in at once.

In order to avoid the escape that would occur if the full parts of the slide-valve had exactly the same width as the ports, slight overlaps are admitted, both upon the inside and outside, of a width slightly greater than that of the compensation passage; and they are also equal, so that the admission and delivery orifices open and close simultaneously and are always uncovered to the same extent. In order to obtain a maximum production of compressed air it is advisable to only close the delivery passage just at the end of the piston stroke, which, moreover, about coincides with the closing of the inlet passage, so that the eccentric should be keyed a little more than 90 degrees behind the crank. This consideration, however, is not imperative; and account must also be taken of balancing the parts in motion and the reactions exerted on the various organs. It is thus that, with the tandem arrangement, it is advisable to diminish the angle of keying between crank and eccentric, to allow the air compensation to begin a little before the end of the stroke.

The annexed diagram represents distribution by a slide-valve of this kind, and above is shown the hypothetical indicator diagram of the progress of the pressures on one face of the piston. If e be the outside overlap equal to i, the inside overlap, a, the width of the ports, m a small quantity, that may be reduced to zero, which the slide-valve travels more than is required by the width of the passage, and p the eccentricity,

$$p = a + e + m.$$

The angle for keying the eccentric (90 degrees + δ) is determined in such a manner that the closing of the passages be effected just at the end of each stroke. The principal positions of the piston are indicated by the Nos. 1, 2, 3 ,4 and 5 in Fig. 8. Between 1 and 2 the compensation of pressure takes place; from 2 to 3 the inlet and outlet passages open; from 3 to 4 they are entirely open, and from 4 to 5 they are again closed. These passages, therefore, remain fully open during the greater portion of the stroke, which considerably reduces throttling both during inlet and delivery.

The lubrication of dry compressors running at great speed requires special care; and it is insured in the Burckhardt com-

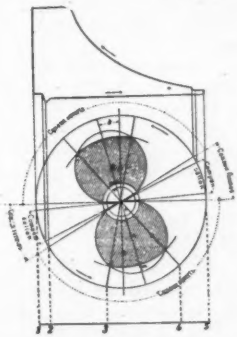


FIG. 8.—DIAGRAM SHOWING POSITIONS OF PISTON.

pressor by automatic lubricators, regulated by a cock terminating in a point and put in communication with the internal atmosphere of the cylinder. The few air-bubbles which penetrate therein during compression drive out the oil during the period of intake.

The mean speed of the air in the distribution passages does not exceed 30 M. (98 ft.). The guaranteed volumetric yield, which amounts to 90 per cent., whatever be the pressure, frequently attains 94 to 95 per cent. The number of revolutions, which varies with the size of the compressor and may attain 200 per minute for those of small size, is generally determined by giving the piston a speed of 1.8 M. (nearly 6 ft.) per second, but not exceeding 2 M. (6 ft. 6¾ in.).

The disadvantage of this compressor (observed M. H. Kuss and M. L. Fevre, in their treatise on mine working) is the heating of the air, which is considerable, while the dynamic yield is not very good. In addition to this the oil is volatilized by the heat; and there is a risk of deficient lubrication of the rubbing parts, so that the slide-valve may set fast. Spontaneous explosions have even occurred, owing to the formation of a detonating mixture by the vapors of the mineral oil employed for lubrication.

DUBOIS-FRANÇOIS AIR-COMPRESSOR.

In order to obtain an increased speed of running, inventors of wet compressors were led to reduce the quantity of cooling water put in motion by the piston, while at the same time raising to its maximum the cooling effect of the water by injecting it in a finely divided state. The water could, however, still fill the dead space at the end of each stroke and cover the delivery valves, if suitably arranged, so as to prevent the re-entry of air; but it cannot cover the piston nor prevent leakage at the circumference, except at the dead point, unless the cylinder be vertical and single-acting. In any case the dead space must be far smaller than in the water-column arrangement.

In this connection the Dubois-François compressors marked an interesting series of steps in advance. The earliest type, shown by Fig. 9, the columns A and B terminating in the delivery valves S′ S′, are well defined. The inlet valves, S S, are rigidly connected together by a rod resting on knife edges or oscillating sectors, which insure the necessary mobility, with the object of diminishing the time of closing at the dead point. The water, brought up by pipes of 1½ mm. (1 1-16 in.) diameter, is injected by nozzles, P P;

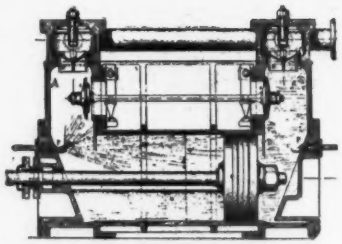


FIG. 9.—WATER COMPRESSOR WITH INJECTION COOLING.

and just in front of them are curved projections, C C, against which the jet is converted into spray.

In a later type, a section of which is shown by Fig. 10, the vertical water columns are very much reduced, so as in reality to only constitute valve chambers. The rod connecting the inlet valves is

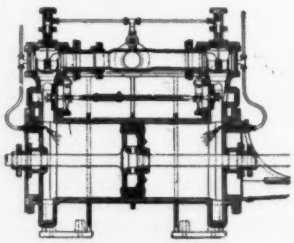


FIG. 10.—A LATER TYPE OF COMPRESSOR SHOWN IN FIG. 9.

made telescopic, so as the yield under the action of a spiral spring, the tension of which may be regulated so as to insure an instantaneous closing of the valves. The closing of the delivery valves is accelerated by the action of a small piston surmounting them, and the top of which is constantly subjected to the pressure of the compressed air, led up by a small copper pipe communicating with the delivery passages of the compressor. The delivery valves are of gun-metal, and the inlet valves of leather with wrought iron fittings, while the piston packing consists of gun-metal rings, lubricated by soapy water mixed with the water injected.

In the latest type of François compressor, shown by Fig. 11, the vertical columns are reduced to their simplest expression, and the dead space to what is only just necessary for the play of the valves. Each inlet valve is fitted with a spiral spring, J, worked by a system of very light rods and

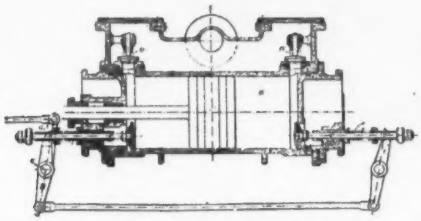


FIG. 11.—A RECENT TYPE OF WATER COMPRESSOR.

levers from a prolongation of the slide-valve rod of the steam cylinder, for hastening and maintaining the closure of the valves; but their action is interrupted during the whole period of intake, so that the valves are free to open completely at the first suction effect of the piston, and in this manner the sharp beat of the valves that occurred during this period of the stroke with the arrangement shown by Fig. 10 has been entirely avoided.

At the same time all injection of water has been suppressed; and a return has been made to its free introduction by the inlet valves, the quantity introduced not exceeding 2 litres per cu. m. (0.1 pint per cu. ft.) of the volume given by the compressing piston, and this abandonment of injection with spraying is due to the relative inefficiency of that system at the high speed of 60 revolutions per second normally, or 80 at the outside.—*J. Walter Pearse.*

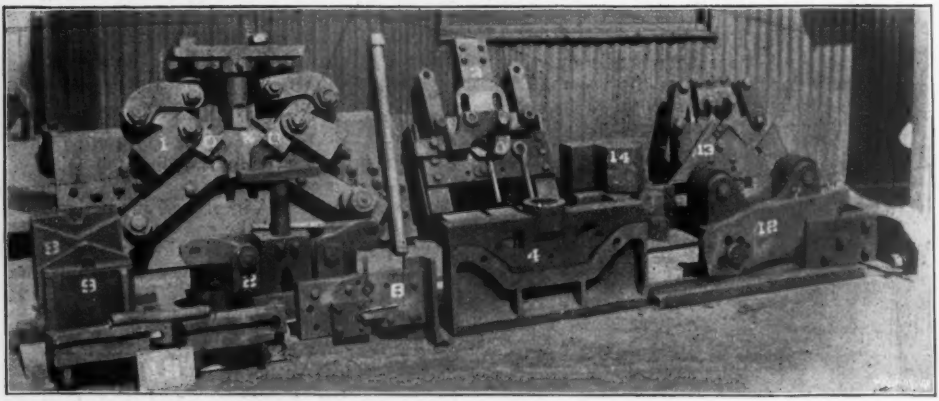
Pneumatic Bulldozer, Pittsburg & Lake Erie Shops.

The subject of the illustrations herewith presented is a 70-ton pneumatic bulldozer in use in the blacksmithing department at the McKees Rocks shops of the Pittsburg and Lake Erie, the machine and tools used in connection therewith having been designed by Mr. A. W. McCaslin, foreman blacksmith. The employment of machines of this order has a marked effect in the reduction of the cost of forgings, as well as in an improvement in the quality of the work produced. Moreover, this machine largely increases the daily output, thereby not only increasing the capacity of the smith shop alone, but facilitating the work passing through the several shops where the amount of work turned out is contingent upon the dispatch with which it is received from the smith shop. The introduction of improved methods in this department and the consequent reduction in the cost of production serves to bring to notice the importance of employing skilled mechanics. The best results are to be obtained from the introduction of bulldozers and like machines, but the utility of these depends entirely upon the design of the tools and formers to be used in connection therewith, and the skill with which they are manipulated. The comparative efficiency of the shop is thus dependent to a large extent upon the mechanical qualifications of the practical smith.

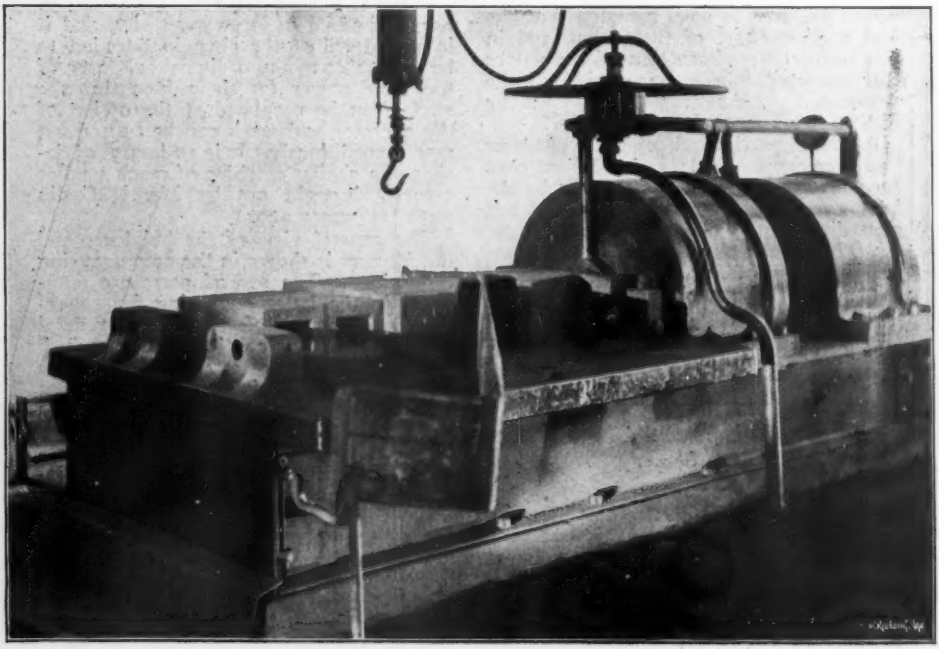
This machine is particularly well adapted to turning out standard shapes of heavy material in large quantities, and it is considered at the shop in question to be preferable to the ordinary bulldozer of the same power for the reason that the stroke can be regulated at the option of the operator and work can be turned out more expeditiously. It is an improved design of a similar machine of much smaller capacity brought out by Mr. McCaslin some two years ago.

The general view of the bulldozer and the formers is shown in the accompanying engravings. The several parts are numbered in the latter engraving for convenient reference. Referring to the general view, the machine consists of two 30-inch cylinders, which are attached to a frame made up of two 16-inch I-beams, the face plate being secured to the top of the beams at the front of the cylinders. The cylinders are placed tandem, and by this arrangement the full power of both cylinders can be concentrated at one point, while the arrangement is such that the pressure from one cylinder can be used independently of the other to economize in the use of air when operating on light work. One hundred pounds pressure in the reservoir will produce a working pressure of 70 tons.

This machine will upset 5-inch square iron when properly heated. No. 1 shows



FORMERS FOR PNEUMATIC BULLDOZER—PITTSBURG AND LAKE ERIE.



PNEUMATIC BULLDOZER—PITTSBURG AND LAKE ERIE.

a tool for heading large bolts, kingpins, collar ends of roller bars, gibs on drawhead pockets, etc.; "OO" are the eccentrics and hooks combined. The eccentrics close the die arms, and when the pressure is released the hooks connect with pins in the arms and open them. The die arms being on an angle, back stops are not necessary, for the greater the pressure the tighter the work is held in place. No. 2 is another style of eccentric tool for heading drawhead rods and bolts of all kinds. The same tool, by changing dies, is used for punching key-ways in kingpins, drawhead bolts, and the like. No. 3 shows a former for bending either the hook or the eye on 1-inch brakebeam hangers. No. 4 is a tool for bending drawhead carriers. No. 9 in the rear and No. 9 in the front show two halves of a tool for forming trainpipe clamps or hangers, one movement making both pieces, the angle and clamp, No. 14, resting on the top, is a "V" tool with two different angles for forming brake carriers from 2-inch and 1-inch iron, one bent edgewavs and the other bent flatwise with the iron. No. 12 is a pair of shears for shearing off round iron from ½ to 1¼ inches diameter. No. 7 is a tool used for bending drawhead pockets, and by changing the rollers, to larger or smaller diameter, this tool can be used for many other purposes, such as bending rod straps, spring saddles, etc. Various other formers are in use for bending arch-bars 4½ by 1½ inch material; engine truck equalizers 4½ by 1 inch; main and side rod straps, coach truck equalizers, drawhead pockets, guard rails, etc. One movement of the machine is sufficient to produce two bends of 90 degrees in tank frame transoms of 8 by 1 inch.

The list herewith given of some of the work that can be done with the machine will afford some idea of its effectiveness. However, a complete list would cover nearly all the wrought-iron parts of locomotives, coaches, and cars that require upsetting, offsetting or bending.—*The Railway Age.*

Cleaning Steel Structures Before Painting.*

Before any paint or other coating of any kind is permitted to be applied to the iron or steel of a bridge or viaduct, all the scale, rust, dirt, grease and other foreign substances, as well as the dead paint, should be removed from its surface, so that the coating may come into intimate contact with a clean surface of metal, and thus give the best condition for firm adhesion of the coating to the metal. No one who has had any experience with such work will dispute this proposition, and yet all over the country bridges are constantly being painted with very slight attempt to secure a clean surface for the paint. The cost of cleaning, and, in the case of new work, the delay in getting the material into the field for erection, are the cause of much of the poor work done in this matter.

The sand blast has been given sufficient trial to make it reasonable to say that such cleaning as is necessary on new work at the shops—that is, removal of mill scale and some rust and grease—can be done at about ½ cent. per square foot of steel surface cleaned, and possibly a little less. This is reported to have been the cost of cleaning such steel plates at the United States Navy Yard at Brooklyn, N. Y., with a moderately perfect permanent plant. Hence it is reasonable to expect that with more experience and an improved permanent plant such work can without doubt be done at this cost or perhaps a little less. On the basis of ½-cent per square foot, the cost per ton for cleaning steel plates would be: For plates 1 inch thick, 49 cents.; for plates ½ inch thick, 98 cents, and for plates ¼ inch thick, $1.96. For shapes: For 7-inch I-beams, weighing 17.5 lbs. per foot, the cost would be $1.35 per ton; 12-inch I-beams, weighing 50 lbs. per ft., would cost about 80 cts. per ton, while heavier sections would cost less and lighter sections more. The average cost for cleaning most plate girder bridges would probably be about $1 per ton. The cost for a truss bridge might vary from $1 per ton for heavy bridges to $1.75 per ton for light bridges. These figures are based on what has been done in only a few places, but upon actual work, and it may be reasonably expected that they are not too high.

As soon as cleaning of this sort shall be required of the bridge shops, and when paint of good, lasting, protective qualities shall be properly prepared, and first coat applied to the metal so cleaned immediately after being cleaned, under proper

*Abstract of a paper by George W. Lilly before the Engineers' Club, of Columbus, O., Feb. 1, 1902.

conditions of weather, it will be possible to maintain our bridges without the necessity of again cleaning with the sand blast for a long period of time. It would be necessary to have such bridges inspected occasionally and when they need repainting but before the paint shall be worn off, or so far destroyed as to seriously affect the metal beneath, a new coat of paint should be applied after a thorough cleaning with scrapers, wire brushes and other tools, such as may be required. We may not hope to see this accomplished before the purchasers of bridges shall require it, because the desire to make good profits will prevent the bridge manufacturing companies from adopting it. It is to be hoped that railroad companies, municipalities, counties and others requiring such structures to be erected will at no very distant day adopt such requirement.

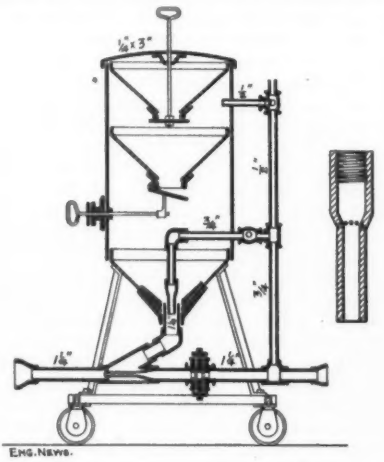
Mr. L. L. Buck, Engineer for the New East River Bridge, specified sand blast cleaning for that structure, and the same should be done for all important bridges and viaducts. For such structures as are exposed to gases from the combustion of coal this is especially desirable. Of course when this is done the additional cost must be paid, but it will no doubt be a saving because of the longer life of the paint, less frequent repainting and longer life of the structures.

The more serious question arises as to the structures heretofore erected, a large majority of which are being rapidly destroyed by rust and corrosion. The viaducts over railroad tracks are more affected than bridges in other locations, on account of the severe trial to which they are subjected. The same is true of trusses and all steel work of train sheds and shops, and to a somewhat less degree as to through railroad bridges. Many of such viaducts and other structures, after standing not to exceed eight or ten years, are found to be in a deplorable condition, although in many cases cleaned by hand and repainted from one to three times. Upon such structures scale will often be found as thick as the original metal, with distinct layers of paint and scales and in many cases with the paint still in fair condition upon the scale. The rust has worked under the paint perhaps as much as through it. For such structures the best hand cleaning is of little effect. After using scrapers, chisels and other kinds of edge tools, loosening scales as far as possible by jarring produced by blows of hammers, then thoroughly brushing with steel brushes, followed by whisk brooms or stiff bristle brushes, much rust and scale very closely adhering to the metal still remains, and very often when the first coat of paint is applied over this the scale will be loosened by the oil softening up the cementing rust.

The only way I know of to effectually clean such metal so that it will be in proper condition to receive the paint is by the use of the sand blast. By employing it every trace of rust and scale and old paint, grease and dirt can be removed and the true metallic surface of the metal exposed to receive the paint, which will then closely adhere to it and afford such protection as it is impossible to secure with the very best hand cleaning or in any other way. Trials of this method on such work have been made, but rarely on a large scale, and generally on a sort of experimental basis. The cleaning of about 50,000 sq. ft. of the 155th St. viaduct, in New York city, was very satisfactory, but the cost averaged about 13 cts. per sq. ft., with a minimum of 10 cts. on a portion of it. Old plates have been cleaned in the United States navy yard at a cost of 4 cts. per sq. ft. with a temporary, somewhat experimental plant. Later a more permanent plant was installed and undoubtedly such work is now done at less cost. The United States Government Army Engineers cleaned nearly 50,000 sq. ft. of steel lock gates and aqueduct on the Muscle Shoals Canal during 1898 and 1899. The plant was erected upon a boat, and seems to have been a fairly complete one. The total cost of cleaning and painting was 5.88 cts. per sq. ft. of surface, and probably the cost of cleaning alone was about 3 cts., or a little more or less, but it is not separately stated. The experience of the P., C., C. & St. L. Ry. Co. in cleaning steel under the High St. viaduct buildings and driveway at Columbus, and on a bridge at Akron, O., indicated that such work would cost about 3 cts., although no accurate record of surface cleaned and cost seems to have been kept.

To secure good results it was determined in the summer of 1901 to use the sand blast in cleaning some of the viaducts of Columbus, O., several of which urgently needed cleaning and repainting,

some parts of them being so badly rusted as to be covered with thick scales and pitted to a considerable extent. Unavoidable delays prevented the commencement of the work until late in November. It was decided to make a beginning on one of the small viaducts, notwithstanding the unfavorable season of the year, and the Front St. viaduct over the L. M. R. R. was chosen as the one to be first cleaned and painted. This is composed of six quite heavy plate girders, with floor system of 9-in. I-beams and buckle plates, and having an exposed painting surface of a little less than 25,000 sq. ft. A 2-in. steel pipe line, 2,300 ft. long, was laid from the receiver of the air compressor at the east end of the Union Depot, and air was furnished by the Union Depot Co. at a charge of 40 cts. per hour for one sand blast machine and 60 cts. per hour for two machines. More than half of the time one machine was used, and the remainder of the time two machines and nozzles, one sand hose leading from each machine. The 2-in. pipe was somewhat increased in carrying capacity by the aid of a 1,300-ft. length of



THE NEWHOUSE SAND BLAST MACHINE USED IN CLEANING VIADUCTS AT COLUMBUS, O.

1¼-in. pipe formerly laid from the compressor connected into the 2-in. pipe under the High St. viaduct. A small receiver of about 9½ cu. ft. capacity was placed at the viaduct to be cleaned and the pipe connected into it and then out of it to the machines. This dried the air better, and a considerable quantity of water was drawn out of it each day by a cock in the bottom, the amount varying with the moisture in the atmosphere. The sand blast machine used is the one invented by J. M. Newhouse, a general foreman of the P., C., C. & St. L. Ky. Co., at this place. It will be seen from the drawing that this machine has some features not seen in other machines. One of these is the arrangement of the air and sandpipes, with nozzle shaped air-siphon pieces in both the air and sand pipe, to facilitate the working of the machine without clogging. The nozzle leading the air through the opening in the bottom of the machine being surrounded with sand, and having small holes extending down and out, the air escaping through them keeps the sand stirred up and prevents its clogging and also keeps the sand chamber filled with compressed air. Three valves are provided, two of which serve to regulate the relative amount of air and sand so as to do the most effective work, and the upper one, a 3-way cock, regulates the supply of compressed air to the upper section of the machine and permits the filling of the machine with sand without stopping the sand blast. These machines are placed upon truck castors to facilitate moving them about where desired, the air being led from the pipe to the machine by a 1½-in. rubber air hose 50 ft. long. The sand hose may be old rubber hose 2½ or 2½ ins. in diameter, sufficiently strong to stand the pressure used, with a nozzle of ½-in. extra heavy gas pipe, which was used because it costs less than tool steel and not many more are required. Two to three each day were worn out, the most severe wear being 3 ins. from the reducer connection to the hose. We used 2-ft. lengths of the pipe, because it was found that the blast is more effective than when a short nozzle is used, and it permits the nozzle man to stand farther from the part being cleaned, and not be so much affected by sand and flying dust. The sand rebounds with sufficient force to frost the glass of his helmet and require the glass to be changed about three times each day. With this machine it has been found that the blast is practically as effective with 100 ft. as with 30 ft. of sand hose.

We usually used not more than about 30 to 35 ft. of sand hose, for the reason

that it is less expensive. The pressure at the entrance to the machines averaged 33 lbs., ranging from 25 to 38 lbs., as shown by a gauge employed at all times, and a record of the pressure was made each day. The sand was dried in two old locomotive ash-pans, which were placed on brick walls high enough to give fire space, and it required the attendance of one man to dry enough sand to keep two machines running. The sand must be cool again before being used, to prevent steaming in and clogging of the machine, and a sand house was constructed to store a small quantity of dry sand.

This viaduct affords only sufficient clearance for the highest cabooses, and hence no scaffold could be swung from the floor I-beams. Above the clearance (or lower side of the plate girders) it is only 12 ins. to the buckle plates. When working over the main tracks, on account of the curves in the tracks leading to the viaduct, three flagmen were required to watch for the trains and warn the workmen to clear the track. These were furnished by the railway company and paid for by the city. The interruption of work by trains amounted to 1½ hours per day, while working over the main tracks, or one-fifth of the working time during the short days of that time of the year; 12,600 square ft. of the viaduct were cleaned and then the weather became so severe that the work was discontinued on Dec. 13. The cost of the work, including flagmen, drying the sand, compressed air and all other expenses, was 3.04 cts per sq. ft. The best day's work was 1,227 sq. ft. at a cost of 1.23 cts. per sq. ft. This was in a favorable location, accessible and uninterrupted by trains, and on the surface of a plate girder; 3,727 sq. ft. of such surface cost 2.37 cts. per sq. ft.

The red lead priming coat, of the mixture before mentioned, was applied as soon as possible after the cleaning was done, the painters following very closely after the nozzlemen, so that it required only one-half hour after the blast was discontinued for the day for the painters to complete the painting of the surface cleaned. No cleaned surface was left over night unpainted. Upon the surface thus secured the paint, warmed as suggested, seemed to make a good coating, firmly adhering to the metal, notwithstanding the unfavorable temperature at which the work was done.

With added experience, favorable weather and longer days, and such improvements in appliances as may be made, it is not unreasonable to expect that,where uninterrupted by trains, this kind of sand-blast cleaning can be done for less than 2¼ cts. per sq. ft., and it is hoped that we may be able to do that well on our viaducts where there is room for a staging, giving clearance sufficient for the passing trains. After once cleaning a bridge in this thorough manner and properly applying the paint, it is expected that it can afterward be maintained in good condition for a great number of years by proper care in inspecting it at frequent intervals and cleaning by hand and repainting whenever the paint shows sufficient wear to endanger the rusting of the steel. We hope to resume this work when the weather is favorable and continue it during the coming season. It is expected that better figures may then be shown than we have at present.

Mr. Keil (Foreman Painter, L. S. & M. S. R. R., Buffalo) in commenting on this paper, said: I believe I was the first man that took up the sand blast on locomotive work, about 16 years ago. It used to cost from $4 to $6 to prepare a new steel tender tank ready for painting. After I perfected the sand blast the work could be done on a small steel tank for $1.25 and a large one would average from $1.50 to $1.75. I noticed after two or three years' service of these tanks that there was a great saving in the cost of repainting. The after results pay well for the time taken at first, but it is also cheaper in the first place. At to the pneumatic painting machine, in places where it is hard to get in with a brush the machine is certainly a good thing and the places that in my judgment would rust out the quickest are under the sills or places that are generally left untouched when painting is done with a brush. I believe that rust in the steel car is the same as a cancer in a person's body; it must be removed down to the bottom; if not, it will keep on. No matter how well painting is done, the rust must be removed first; otherwise it will rust under the paint. I used to be very careful in doing a steel locomotive tank. As soon as I was through sand blasting I had it painted at once. In one hour's time, with a powerful magnifying glass, the tank would show rust, no matter if it were a dry day. I found that it paid to put the paint on at once.

Notable Ship Riveting by Pneumatic Tools.

It is now not only highly advisable, but, in the case of the huge steamships now common, absolutely imperative, to substitute power in place of hand riveting in shipbuilding. Undoubtedly, a task lying ready to the hands of progressive shipbuilders is to render possible the complete application of power riveting in shipbuilding. Riveting by hydraulic tools is, of course, quite a common practice already, but this system has its limitations, in its application to work to be done *in situ* especially. The quality of portability in the tool is here a regulating condition, and the ratio of weight to power exerted in hydraulic tools is inadmissibly high. Consequently tools of this class are a disadvantage, if not entirely inapplicable, when tools have to be brought to the work as in binding a ship's structure. Powerful appliances in the way of travelling cranes and gantries for transporting and holding the tools to their work certainly minimize the drawback of excessive weight; but the cost involved is such as will scarcely justify the adoption of these appliances, except in very exceptional cases, and even then the field of application is restricted. For the most complete and all-round satisfactory system of power riveting in shipwork, we must look to the pneumatic tools already thoroughly established in American yards and now almost equally well known in England, in spite of the obstacles and restrictions to their use brought into play by the prejudices, jealousies and ignorance of the classes of artisans their introduction affects. The all-round satisfactoriness alluded to is not alone in the fact of the riveting being accomplished with much greater speed, less cost, and with at least equal thoroughness, but largely consists in the applicability of the system to tools and operations closely associated with riveting. Pneumatic power for drilling, seaming, chipping, cutting, and caulking, is even more indubitably established than for riveting operations, hence its cumulative potency as the medium for riveting. In all our shipbuilding centers, notably the Clyde, the Tyne and Wear, pneumatic tools for drilling, caulking, chipping, etc., are already introduced and in constant use. In the case of riveting tools, there is an equal readiness on the part of employers to introduce them, and in the case of most of the large firms, tools for riveting are as liberally ordered as others, but their use is retarded by the economic or labor questions involved. Employers, in return for the installation of expensive tools, naturally desire to secure some reduction in the rates paid to those who use them, but so far the attitude of the ordinary riveting operative has been that of eyeing the pneumatic riveter askance, and for working it, insisting on the price per 100 as in the case of handwork. In some cases where riveting tools have been put to work, the autocratic riveting squad have had to be paid for simply standing by, all the work meanwhile being done by a mere stripling. The tools now finding their vocation in British and Continental yards are those of the "Boyer" type, supplied by the New Taite Howard Pneumatic Tool Company, Limited, whose striking demonstrations of the capabilities of pneumatic tools for all sorts of shipbuilding, boilermaking and structural iron work generally at Glasgow Exhibition last year, many readers will doubtless remember. The work then accomplished was in every respect closely analogous to the actual work undertaken in large marine and locomotive shops and in shipyards, and the period of exhibition doubtless left its due and potent impressions even on the prejudiced workman. Some doubt has been entertained as to the quality of the riveting work done where large rivets and many thicknesses of plating are concerned.

We are in a position to draw attention to a very notable instance of heavy work done, intended to withstand the test of severe daily ordeal. This was on the large Clyde-built Atlantic steamer "Zeeland," of the International Company's fleet, while in dock for repair at Southampton, having, like previous vessels of the same design, given symptoms of local weaknesses, as evidenced by the loosening of rivets.

At the desire of the owners, who have had a sister ship to the "Zeeland" built in America, the riveting in which has been wholly done by "Boyer" tools, pneumatic riveting was adopted in the repair work on the "Zeeland." The plate was 1½ inch thick, and the plating and angles to which it was attached in some places formed 4 and 5 ply, 4¼ inch and 5¼ inch thick, necessitating rivets 6¼ inch to 8 inch long. The rivets were 1⅛ inch diamater, and altogether between 280

and 290 were driven with the tool. The air pressure was 100 lbs. per square inch. The rivets before being driven projected as much as 2¾ inches through the plate, this being necessary in order that they might provide enough metal to fill the countersinks—which were extra large—and leave metal sufficient to form the heads. Where there was a clear run of work, and with the necessary gear and rigging fixed, these very heavy rivets were driven at the rate of one per minute. The work was done to the entire satisfaction of the surveyors appointed to supervise the repairs, as well as those of the Board of Trade and of Lloyd's. It is of interest to add that the tools and the workmen employed in this case are now engaged on the repair work being done to the Cunard steamer "Etruria," in the Canada Dry Dock, Liverpool, after her recent breakdown in the Atlantic. At present operations are confined to heavy chipping and drilling by the tools, but in the course of a week or so, when the new stern post has been put in place, the tools will be called upon to deal with riveting of the heaviest description, the diameter of the rivets being 1½ inch. The work is being carried out by the New Taite Howard Pneumatic Tool Company, Limited, and no impediment is placed in the way of any one wanting to inspect the notable work being done by their pneumatic tools.—*The Syren and Shipping.*

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz.: all communications should be written on one side of the paper only; they should be short and to the point.

One of our correspondents writes us as follows:

"Will you please inform me about what is the average velocity in ft. per minute allowed in air compressors both for the intake and exhaust valves? Is it the same for single and two-stage compressors?"

It is very difficult to answer these questions in anything like a satisfactory manner, as there is a great variation in the velocities used by the different manufacturers. In a general way we find that the velocity of the inlet air—that is, the speed with which the air enters the cylinder of an air compressor—varies with different makes and different sizes of the same make, and ranges from 3,000 to 8,000 feet per minute for 100 lb. compressors.

The discharge valves are, naturally, smaller than the inlet, because by the time the air is ready to pass through these its volume is being decreased in almost direct proportion to the final pressure. In round numbers the discharge velocity seems to be from 800 to 1,800 feet per minute. In the case of two-stage compressors there seems to be no uniformity whatsoever, and the velocity at the inlet end may be figured anywhere from 3,000 to 8,000 feet per minute.

Notes.

The Cleveland Pneumatic Tool Company have appointed The Compressed Air Machinery Company, of San Francisco, Cal., to represent them on the Pacific Coast.

In the Kalgoorlie Gold Mine, West Australia, the cumbersome method of mechanical agitation in the large steel vats has been superseded by the process of agitation with compressed air.

His Majesty, King Edward VII., recently paid a visit to Whitehead's Torpedo Works at Portland, England. The arrival of the royal party was greeted with numerous torpedoes discharged in the air and filled with compressed air.

The Pneumatic Ore Concentrating Company, with a capital stock of $500,000, has been incorporated under the laws of the State of New Jersey. It is an Ohio concern, and its charter permits the company to manufacture by-products of iron, steel, etc. The incorporators are Jay J. Snyder, D. M. Stewart, of Xenia, O., and John O. Wilson, of Camden, N. J.

The contract for the pneumatic installation required by the India office for the Bombay Dockyards has been granted to the International Pneumatic Tool Co., Ltd., of London. This company have also

received the two large contracts for the pneumatic tool installation for the Bengal Nagpore Railroad Company, to be installed at the Kharpur Workshops, India.

The Chicago Pneumatic Tool Company has recently been awarded contracts for three of their large "Franklin" Air Compressors for the Philadelphia and Reading Railway, and two compound air compressors of 2,000 cubic feet capacity for the new car shops of the N. Y., N. H. & H. Railroad, of Readville, Mass., and one for the Atchison, Topeka and Santa Fe Railroad.

Familiarity with danger leads very often to trouble. Witness the case of the workman at the ship-building yard near Toulon, France, who was killed while handling a diving-bell apparatus. He released the connection at the end of the communicating shaft, and the compressed air blew him with terrible violence against the top of the shaft, crushing his body beyond recognition.

With the Philadelphia Pneumatic Tool Company inquiries, both from foreign and domestic sources, have been numerous and some good orders have been taken, foreign and extreme Western trade being particularly strong. A large number of rammers, clippers and hammers have recently been shipped for export to various European countries, and deliveries to various concerns in all parts of the United States have been made.

To find the amount of air that can be produced by different size air cylinders: Find the area of the cylinder and multiply that by the stroke; then multiply result by 2 if it is a Straight Line Compressor; by 4 if a Duplex Compressor; or by 2 if a compound Duplex Compressor. Divide this result by 1728, which will give the amount of air per stroke, and then multiply by number of strokes per minute.

The compressor for the United States Mining Company, at Bingham, Utah, is from the works of the Allis-Chalmers Company. The size of the machine is as follows: Steam cylinders, 22 and 40 ins. in diameter; air cylinders, 36 and 22 in. in diameter, all 40-in. stroke. The compressor runs condensing and compounds the steam used and air delivered, delivering about 3,400 cu. ft. of free air per minute. The engines for the smelter at Bingham Junction are beginning to arrive from the Allis-Chalmers shops.

The Moundsville Coal Company has received from the Norfolk Iron Works a large compressed air machine, weighing probably 40 tons, to run fourteen compressed air mining machines. This is a very great improvement and will take the place of several men. The coal company contemplates making many more important improvements in this as well as in other lines. The improvments will be so conducted that no men will be thrown out of employment for some time, at least.

Fraser and Chalmers, Limited, Erith, have lately secured an order from the Glyn Colliery Company, Tonyrefail, South Wales, for a large horizontal Riedler Air Compressor, with steam cylinders 23 in. by 35 in. by 54 in. stroke,, and air cylinders 22 in. by 36 in. by 54 in. stroke. The compressor is to be constructed for 120 lbs. initial steam pressure, to deliver air at 80 lbs. pressure. The steam cylinders are to be of the Fraser and Chalmers' standard Corliss gear type, fitted with the Whitmore air-governor.

The repairs on the steamship "Zeeland," at Southampton, which are being executed with pneumatic tools, are being carried out by Messrs. John Brown & Co., Ltd., of Clydebank, assisted by Messrs. Mordey, Carney, Limited, of Southampton, who say that they have used pneumatic tools in their works for some months. The New Taite Howard Pneumatic Tool Company, which owns the European patents of the tools in question, states that for 1⅛ in. rivets the time occupied has been one minute per rivet, and only two men are employed instead of three.

The efficiency of a compressed air power transmission plant varies considerably according to the design of the plant, the conditions under which it works and the uses to which the air is put. The losses are made in the following manner: 1. Engine and compressor friction. 2. Friction in pipe line. 3. Loss in valves and

connections. 4. Loss in the motors using the air. With a mine plant as ordinarily designed the following experiences may be obtained: Engine and compressor, 65 per cent.; pipe line, 96 per cent.; motors, 80 per cent. Efficiency of the whole system, about 50 per cent.

There are forty compressed air drills at work on the Sodbury Tunnel of the Great Western R. R. (Wotton Bassett to Patchway), the construction of which is in charge of Messrs. S. Pearson & Son., Ltd., of Westminster, England. A year ago this work was stopped by the inrush of a very large quantity of water, but it has been rapidly progressing since then, and in spite of a flooding of a portion of the works, nearly one and a quarter miles have been excavated. There are about 1,800 men at work on the tunnel and it is expected to be finished in about two months.

Crossing the River Clyde at Glasgow, the river bed is especially poor and considerable difficulty has been found in constructing and maintaining the quay walls along the river bank for bridges, etc. At one point we hear that a wall is being built for the fourth time, the previous ones having failed owing to weak foundations, either due to the river bottom or to bad judgment on the part of the contractor. The wall now under construction is being built on a steel caisson which was sunk by the penumatic process, the wall of brick and concrete being built as the caisson sank into place.

Various schemes for the mutual benefit of the human race are popping up every day and everywhere. Most of them go up in the air like toy balloons and so sail away never to return. In a London paper (note that the news has first travelled across the seas) just read is a description of a patent granted to Professor Thede of Chicago, U. S. A., to utilize wind mills for power accumulation in the shape of compressed air. Professor Thede proposes to compress air until it is liquefied and then to make use of it for innumerable purposes. It is said that he claims to have sufficient financial backing to put his scheme to a practical test. Let us wish him "good luck."

The Mysore Gold Mines of India have the peculiar interest of being (in that country of hand work) among the few who employ up-to-date methods and machinery. The Kolar Fields extend for over ten miles, but the most productive and busy part centres around the Mysore District. Here are 14 shafts, the most important having reached a depth of half a mile. Near by are stationed the air compressors, designed at the present time to drive 24 rock drills (3½ inches). This is the main power house, although in different parts of the mine air compressors have been sprinkled about, between them all supplying air to sixty rock drills, fourteen donkey-pumps and three air hoists.

The postmaster general has appointed the following committee to visit various cities and investigate conditions governing a need of pneumatic tube service, and prepare a report for Congress: John M. Masten, chief clerk of the first assistant postmaster general's office; J. H. Crew, superintendent of railway adjustment, postoffice department, and V. J. Bradley, superintendent of the New York division of the railway mail service. This committee will act in conjunction with the postmasters of the following cities, which heretofore have been recommended by the department as places where pneumatic service should be established: New York, Brooklyn, Philadelphia, Boston, Chicago, St. Louis and Washington.

In many cases compressed air experiences considerable loss of power, but the inevitable deficiencies may be greatly increased by needless defects in the appliances. To get the best possible results we ought to have well-designed and well-constructed air compressors, of sufficient power, and the valves should be controlled mechanically. The compression should be by the compound system, so as to deal effectively with the heat generated. The pipes conveying the compressed air should be such that the linear velocity will not exceed 6,000 feet a minute. In front of each engine using compressed air there should be a receiver to allow the moisture in the air to settle and be drawn off. Careful attention to, and compliance with, these conditions will give us minimum loss; neglect of these conditions will give us maximum loss.

To understand the action of an air vessel we must have well in mind the fact that water is practically incompressible, and the bucket or ram of an ordinary pump reverses its motion for each separate stroke. Unless some precaution is adopted the unyielding pump, acting on an unyielding liquid, would produce a succession of severe shocks. The air vessel is always partly full of air, and is open alike to the delivery column and to the pump. The air in this air vessel is a highly elastic cushion, and successfully avoids what would otherwise be a series of injurious shocks. The air vessel loses its efficiency if the water is allowed to absorb all the air. This should be prevented, and there are methods of keeping the air vessel charged with the needful amount of air.

The Industrial Undertakings Company, Ltd., of London (which is a firm with a name), have put on the market what they style as the "Champion" coal cutter which is worked by compressed air. This machine is simple in construction and can be used for either nicking or cutting the coal. The drill once set to work, the cutting-bit strikes the coal at the prodigious rate of 350 blows per minute. When used in a coal-mine the machine dispenses entirely with the use of explosives for breaking down the coal. It is claimed for this machine that, with skilful handling, it is capable of making a cut in fairly hard coal of from 50 to 60 square feet per hour. The consumption of compressed air amounts to about 12 cubic feet per minute. If an air drill is used, and if an electrical drill is employed, from one to two horse-power.

One-hundred-miles-an-hour trains at Berlin, Germany, called the "Allgemeine Electriciats," have a 14-mile run with steep grades for even an ordinary steam locomotive, yet here is used an electric motor. There are three cars to a train, each car having three compartments. At either end of the car are the electrical apparatus operated by compressed air and used also for controlling the working of the car and in connection with the air brakes. Beneath the car are two duplex pumps with 190 revolutions per minute, which force air into two cylinders having a combined capacity of 14 1-3 cubic ft. at a pressure of 120 lbs. Two air cylinders are utilized for working the controller which cuts into the electric motors. These two cylinders are of different diameter and work in opposite directions and the motors are put in one at a time.

With the exception of a few very restricted applications of "Pneumatic Transport," the use of compressed air for transmitting power was first realized in a practical form for driving the Mont-Cenis Tunnel, when Sommeiller's water-column compressor was invented for driving the rock drills from a distance and greatly contributed to the achievement of that grand undertaking. Owing to the special facilities which this method of transmitting power affords in underground workings, its employment has quickly spread in mines, where it has received numerous and important applications; and although electricity has proved a formidable competitor of late years, and may be destined to supersede it in many cases, the field of action that can be covered to advantage by compressed air remains very vast, and can but still further extend with the development of mechanical plant for mine working. "This method of power transmission, therefore, merits special attention," remarked M. H. Kuss and M. L. Fevre, in their treatise on mine working.

Mr. J. W. Duntley, President of the Chicago Pneumatic Tool Company, has just returned from a trip through Europe. While there he secured orders for an aggregate of 2,700 "Boyer" and "Little Giant" Pneumatic Tools, as well as 25 "Franklin" Air-Compressors, for early delivery. Mr. Duntley states that the Europeans now realize the absolute necessity of using labor-saving tools so as to reduce the cost of manufacture and counteract the influence of the "American Invasion" (which is causing widespread alarm in commercial circles) and enable them to compete for the markets of the world.

The unprecedented increase in the sales of pneumatic tools in foreign countries recently, may be attributed, in a measure, to the cause above mentioned and also to the fact that the opposition to pneumatic tools by workmen, on account of their labor-saving qualities, has been entirely overcome. The various plants of the Chicago Pneumatic Tool Company are taxed to their utmost capacity, and will have to be

greatly enlarged in the near future in order to meet the ever-increasing demand for their products.

The University of Wisconsin will open the second summer session of its summer school for apprentices and artisans on June 30th, which session will close August 8, 1902.

This school is intended primarily to give to stationary engineers, superintendents of power stations, machinists, artisans and apprentices in various trades such mathematical, laboratory and shop instruction as would be found of most practical value to persons in these employments, and which would be imparted in the limited time of six weeks.

Any person over sixteen years of age, speaking the English language and having a fair knowledge of arithmetic, will be admitted. The school has a faculty of ten, composed of regular professors and instructors from the faculty of the College of Engineering.

Correspondence school students will find the opportunities for laboratory and shop work here offered particularly helpful.

The tuition fee for the term is fifteen dollars for all courses. In addition to this, there are laboratory fees of five cents per hour for all time spent in such practical work.

At a meeting of students of the Institution of Civil Engineers held on Friday evening, April 4th, in London, Mr. Basil Mott, M. Inst. C.E., in the chair, Mr. L. G. Crawford, Stud. Inst. C.E., read a paper on "Compressed Air and its Applications," of which the following is an abstract: In this paper the author investigates the theories which govern the design of compressed air plant, indicating the advantages which result from the use of multiple stage compressors and the economies effected by re-heating. Detailed descriptions are given of the D'Auria, Taylor and Boreas air compressors, and also of those manufactured by George Wailes and Co. The results of some trials of the latter are given and commented upon. The author then describes the applications of compressed air in connection with riveting, hoisting, despatch and traction, sub-aqueous excavations, etc. In conclusion, the advantages to be derived from the use of compressed air under certain conditions are briefly indicated. The reading of the paper was followed by a discussion, in which Messrs. A. J. Deane, E. A. Davies, F. H. Clough, H. E. Wimperis, and A. M. Arter, Studs. Inst. C.E., took part.

Yankee methods and British workmen are still performing feats that startle the English public, who have hardly had time to close their mouths from wondering at the records made in brick laying at the British Westinghouse Company's works at Manchester, when they are called upon to admire the huge chimney stack of the generating station of the Mersey Railway Company, at Liverpool. Commenced about Christmas time, the stack, which is about 250 feet in height, has been completed already, and stands as a record-breaker as far as expedition in building is concerned. The work has been carried out by the British Westinghouse Company, who have the contract for converting the Mersey Railway tunnel from steam to electric traction, and the work has been done by British labor under the direction of Messrs. J. Stewart & Co., famous for record-breaking time in the construction of the Manchester Works, the Galveston docks and the renowned grain elevator, "Kalumet K." From nearly every part of Liverpool the Mersey chimney, decorated with the American and British national flags, stands out plainly on the sky-line as the highest structure in that part of Cheshire.

The Homestead and Mifflin Street Railway Company, financed by business men of Homestead, Pittsburg and vicinity, has recently begun the construction of a line from Homestead, Pa., to Lincoln Place, in Mifflin township, a distance of three and a quarter miles. It will cost $100,000, and is expected to be in operation by July 1. Later additions will be built to the road. Next spring a branch will be constructed to Whitaker, the residents of which now have no street car facilities. This branch will cost $75,000, $33,000 of which, according to an estimate, will be needed for erecting a bridge across Whitaker Run, in Munhall Hollow. The bridge will be about 70 feet high.

The new road will prove a great convenience to the people of the Third ward of Pittsburg, Homestead, and to the resi-

dents of the hill district south of the borough, where there are practically no transportation facilities. The project also includes the improvement of a large amount of land along the route for building lots. A fare of five cents will be charged. The Laclede Car Company of St. Louis has been awarded the contract for the cars. Westinghouse motors will be used and the cars will be equipped with the Westinghouse magnetic brake. The rails will weigh 90 pounds to the yard and will be joined with a recently patented coupling, which insures easy travel.

The Ehrenfeld Plant of the Webster Coal & Coke Co., whose properties, owned and leased, amount to 51,000 acres in all, are situated on the main line and branches of the Pennsylvania Railroad, where the system crosses the summit of the Alleghanies, between Altoona and Johnstown. This whole territory is underlaid by coal beds belonging to the lower productive coal measures or Freeport series, which outcrop at the southern end and permit the coal to be mined by drift openings. In regard to the kind of mining, whether pick or machinery, to use the words of the superintendent of this division, Mr. J. L. Nicholson, the coal is of a woody nature and requires a machine of the puncher style, delivering hard blows of greater length of stroke than the short, quick stroke used with such telling effect in hard, brittle coal.

Six Sullivan and three Ingersoll punchers are used in No. 6 and No. 8 openings. In No. 3 mine two Sullivan machines drive the main heading, and pick mining is used in the other working places here as well as throughout No. 5 opening.

The compressor plant includes two Ingersoll compressors delivering air at 85 pounds pressure and furnished with steam by three tubular boilers of 100-horse power each, made by the Eagle Iron Works, of Terre Haute, Ind. The compressors have 20-inch stroke and 24-inch air cylinder.

A method for measuring the volume of air delivered by a compressor (checked by Hirn and communicated by Professor Rateau to the authors of Fanchon's *Mine Working*, who describe and illustrate the two-stage compressors of the Ingersol-Sergeant Drill Co.,and the Rand Drill Co.) consists in exhausting the air through a small tuyère, or nozzle, the diameter of which has been calculated by means of a preliminary and approximate estimation of the volume delivered, so as to correspond with this volume at the pressure given by the compressor. Inasmuch as such pressure is generally more than double that of the atmosphere, the volume delivered only depends upon this pressure and the final sectional area of the nozzle. This volume is estimated at the initial temperature of the air before entering the nozzle and should be reduced to that of the outer air, so that these two temperatures must be taken. For a converging nozzle the volume delivered is expressed by the formula

$$D = 18.9\, s \sqrt{\frac{To}{273}}$$

in which D is the volume delivered in litres (1 litre = 61 cu. in.) per second at the pressure given by the compressor, s the sectional area of the orifice in square centimetres (1 sq. cm. = 0.155 sq. in.), and To the absolute temperature in centigrade degrees of the air before entering the nozzle.

The new shops of the Philadelphia Pneumatic Tool Company, situated at 21st St. and Alleghany ave., Philadelphia, Pa., are completed, and the company is now doing business at the above address. The power plant is installed and everything is in readiness for the full operation of the new plant. About $10,000 worth of new machine tools, to be delivered early in June, have been ordered, and with these new tools the company hopes to be able to relieve the very much overcrowded condition of their works and be able to make more prompt deliveries than heretofore. About 150 men will be required immediately to do the work, which at present they are trying to do in their crowded quarters with 95 men. The Philadelphia Pneumatic Tool Company has recently placed upon the market two new sizes of Rotary Drills and have perfected an improved Riveting Hammer, which is being made in three sizes, having capacities varying from ¼-inch to 1¼-inch rivets. They report that they have recently received orders aggregating nearly 200 tools from one of the largest shipyards in the country, and this, together with a lot of railroad and other trade makes an unpre-

cedented rush of business. They are making preparations for an elaborate display of their tools in a working exhibit at the Master Mechanics and Master Car Builders' Convention, which is to be held in Saratoga from June 18th to June 25th, and visitors at the convention will do well to visit this display.

We have heard the subject of liquid air discussed with so many "castles in the air" that nowadays we have become skeptical and shrug our shoulders when we hear the wonderful things promised with this motive power. If the subject waxes too warm, we almost feel like following the example of the naughty boy who put his fingers in his ears and fled. Nevertheless, this power has been chained and utilized in many ingenious ways, and among the companies formed to accomplish this is the Air Power and Automobile Company, of Pimlico, London, which has certainly turned liquid air to some account, though how far it is going to revolutionize methods of traction and power we must wait to discover. At the company's works at Pimlico there was recently a very unique demonstration of a little motor car driven by liquid air. Powerful engines were compressing the air of the atmosphere and reducing it in temperature under the pressure till it liquefied at more than 300 degrees below zero. The lid of the back portion of the car was then removed, revealing a felt-covered receptacle, with orifices carefully screwed up. A tin vessel was then filled from a tap beneath a registering gauge on a large, wood-covered tank. A bluish liquid was the result—this was liquid air. It was then emptied into the tank on the car and up rose a cloud of cold steam, chilling the hand if held in the mist. A considerable quantity of this liquid was necessary for the charge, but when the signal was given off sailed the car as daintily and as well behaved as the heart could wish, free from vibrations and other objections, responding to the slightest touch of the lever. The cost of running this car has been estimated to be about a halfpenny per mile. Their great difficulty at present would be the absence of storage stations where the supply of liquid air might be replenished. Perhaps, if we could see into the future, we might see advertised in all country villages: "Liquid air sold here by the gallon." That would certainly help science along and, incidentally, the liquid air companies.

Upon the erecting floor of the J. George Leyner Company are a pair of large compressors, exact duplicates of each other. The history of the order for these compressors has been given to us and, as an illustration of what American manufacturers are doing in foreign markets, the story is worth repeating.

About four years ago a prominent mining and mechanical engineer from Australia was asked, while in Denver, to recommend an air compressor for installation in a mine which had formerly been under his management. After due investigation he recommended one of the largest air compressors then built by Mr. J. G. Leyner. The purchase and installation followed. A year later the twin of this compressor was shipped to the same mine. Extended development of the group of properties owned by the purchasing company created a demand for more air compressors. During all of this time no personal acquaintance has existed between the officials of the mining company and the members of the Leyner firm. Yet with the development of the mines have come frequent cable orders until nine Leyner compressors are now installed there.

When the fact is considered that, except for their correspondence relations, manufacturer and purchaser are strangers to each other; when it is considered also that the mine and factory are some 7,000 miles apart; that American machinery is subject to import duty and is sold in competition with the manufacturers of the world, this unbroken record appears somewhat remarkable.

A neighboring mine required a compressor. The only salesmen the Leyner establishment had in the field were the nine compressors there and the good opinions they had won, yet the order was cabled for a Leyner machine. This was about a year ago. The twin machines now building at the factory are going to the purchasers of this tenth compressor. They are of the new type of the Leyner compressors, for which the manufacturers claim great improvement over former models. There could be no doubt of their being effective salesmen, adding still further to the reputation of machinery of American manufacture abroad and to that

of Denver as a source of supply for mining machinery.—*Mining Reporter.*

The building of the second tunnel under the River Thames, that of Greenwich street, has also, like its twin brother, the Baker street tunnel, been operated and worked by the means of compressed air.

During sinking the caissons the opening in each shaft for the tunnel has been closed by a "plug" formed of steel plates fitted between girders in such a way as to be removable singly when the shield was ready to start. This steel plug was removed by gradually substituting, four feet behind it, a timber diaphragm, and filling the space between this diaphragm and the face with plugged clay.

The cast-iron lining was similar to that used in previous works of the same kind, but some improvements had been made in details to obtain better water-tight joints. All bolt-holes were made with a short portion bevelled off, and when the bolts were put in, lead washers were put on them, and, on the bolts being screwed up, the lead completely filled the space round the bolts at each end made by the bevelled edges of the bolt-holes. This arrangement had proved very successful, and comparatively few bolts had been found leaking when the air-pressure was removed. Into the joints between castings soft lead wire was hammered before caulking. The shield, of the "trap" or "box" type, was 14 feet 6 inches in length and had an external diameter of 13 feet. The cutting edge was made in thirteen segments, each segment having two 6-inch teeth cast on it, and immediately behind the cutting edge was a circular built box girder. Certain alterations suggested by experience had been made in the shield. The method of tunneling differed from previous similar work only in the use of face-rams for holding up the timbering of the face. The rate of progress had been exceptionally rapid, an advance of 10 feet per working day having been made over all the tunnel except a short length in open ballast on the Greenwich side. This was attributed mainly to the favorable character of much of the material excavated.

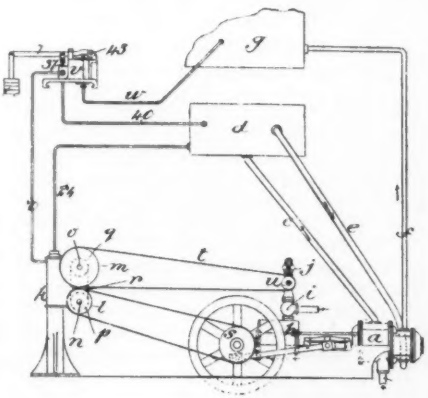
An attempt had been made to eliminate the carbonic acid from the air supplied to the tunnel by means of caustic soda. With this object an apparatus consisting of boxes or rectangular tubes of wood, one above the other, open at one end, and having sliding doors at the other end, had been devised. The ends, fitted with doors, were connected to the air-inlet of the tunnel by a conical box, the connection with the air-pipe being made air tight by a flexible joint. By opening one or other of the sliding doors the air could be made to pass through either the upper or the lower tube as required. These tubes had removable sides, and each contained eight movable wire boxes containing pumice stone broken small, which, before being put into the tubes, were dipped in a saturated solution of caustic soda.

U. S. PATENTS GRANTED APR. 1902

Specially prepared for COMPRESSED AIR.

696,461. SPRING AIR-GUN. William F. Markham, Plymouth, Mich. Filed July 9, 1900. Serial No. 22,935.

696,504. REGULATING DEVICE FOR AIR-COMPRESSORS. Henry C. Sergeant, Westfield, N. J., and William Prellwitz, Easton, Pa., assignors to the Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed Feb. 28, 1901. Serial No. 49,211.



The combination with an air-compressor and a motor therefor, of a motor-controlling governor, a speed-varying mechanism consisting of two expanding and contracting pul-

leys and a belt between them, means for driving one of said pulleys from the motor-shaft, means for driving the governor from the other of said pulleys and means for simultaneously expanding one and contracting the other of said pulleys under the control of the pressure of the air delivered by the compressor.

696,531. PNEUMATIC CONVEYOR. James M. Akers, Gays, Ill. Filed June 1, 1901. Serial No. 62,746.

A device of the class described, a fan, a discharge-chute leading from said fan, a feed-hopper, a chute leading from said hopper into the eye or inlet of said fan, a chute leading from said hopper into the discharge from said fan, and means whereby the material fed into said hopper may be conducted into either of said chutes.

696,553. PNEUMATIC STACKER. Daniel Dow, Grand Forks, N. D. Filed Oct. 24, 1901. Serial No. 79,841.

A pneumatic stacker, the combination of a main wind-tube, a fan, a chaff-floor disposed above the fan, a main air-duct, a chaff air-duct having an inlet near the lower part of the fan and a throat located at the bottom of the chaff-floor.

696,730. COMPRESSED-AIR CONTROLLING DEVICE FOR SAND-DISCHARGERS. James Farley, Waukesha, Wis. Filed Sept. 13, 1901. Serial No. 75,258.

The combination with an engineer's brake-valve, and its handle, of a device secured to said handle to move therewith, and provided with an inclined surface; an independent valve-casing, having a channel there-through; a valve intercepting said channel and having a stem projecting beyond said casing; pipe connections between one end of said channel and the main reservoir of the brake-valve; another pipe leading from the other end of said channel; and means connected to the said projecting valve-stem for engagement with the inclined surface of the device secured to the brake-valve handle, and thereby controlling the admission of air to and regulating its passage through said channel.

696,803. ANGLE-COCK ADJUSTER FOR AIR-BRAKES. William S. De Camp, Chillicothe, Ohio. Filed Dec. 31, 1901. Serial No. 87,885.

An angle-cock adjuster comprising pneumatic means for turning the plug of said cock, and a by-pass valve for carrying the air around the angle-cock plug, said by-pass valve being located in the casing of the angle-cock.

696,843. PNEUMATIC-DESPATCH TERMINAL. Erbine C. Phillips, London, England, assignor to the Lamson Consolidated Store Service Company, Newark, N. J., a Corporation of New Jersey. Filed Dec. 13, 1899. Serial No. 740,174.

An upward-discharge terminal for pneumatic-despatch-tube systems, comprising in combination a substantially semicircular tubular member to be secured at one end to the upper end of the receiving-tube and constituting the discharging element of the terminal, a short straight tubular member adapted to be secured to the upper end of the sending-tube directly beneath and within the curve of said semicircular member and constituting the sending element of the terminal, and an air-return-pipe section uniting said curved and straight tubular members laterally near their discharging and receiving ends respectively, the space bounded by and included within said parts being entirely open, whereby the sender is equally accessible from all sides of the terminal.

696,972. SUBMARINE BOAT. John P. Holland, Newark, N. J. Filed Aug. 7, 1901. Serial No. 71,131.

A submarine boat or vessel having in it a closed tank containing a liquid hydrocarbon, means for charging and supplying the liquid from same, a ventilating-pipe extending from the upper part of said tank out through the shell or hull of the boat, a check-valve controlling said pipe and opening outwardly and means for automatically controlling the admission of air to said tank from the interior of the boat to replace the liquid used.

697,003. AIR BRAKE. Joseph E. Normand, Watertown, N. Y. Filed May 4, 1900. Serial No. 15,489.

697,015. AIR-PRESSURE SYSTEM OF LIGHTING. James E. Raff, Garwin, Iowa, assignor of two-thirds to Harry V. Moyer and Edwin Beery, Garwin, Iowa. Filed Mar. 18, 1901. Serial No. 51,749.

An apparatus of the class described. the combination of an air-reservoir, a fuel-tank, a main air-pipe extending directly from the air-reservoir to the fuel-tank, a main supply-pipe extending from the bottom of the fuel-tank, a supplemental pipe extending from the main supply-pipe at a point adjacent to the plane of the bottom of the fuel-tank to the air reservoir and having an upright portion adapted to contain a portion of the fuel and provided with a valve 16 and with a cock 17 located below the valve and adapted to be open to permit the fuel to rise in the upright portion of the supplemental pipe, said supplemental pipe forming a passage or conduit for the air when the tank is cut out for re-filling, and valves for cutting out the tank.

697,055. INNER TUBE FOR PNEUMATIC TIRES. Frank A. Wilcox, Erie, Pa. Filed Feb. 6, 1902. Serial No. 92,803.

697,171. COMPRESSED-AIR WATER-ELEVATOR. James R. Ricketts, Kingfisher, Okla., assignor of one-half to George W. Wilson, Kingfisher, Okla. Filed Dec. 3, 1901. Serial No. 84,561.

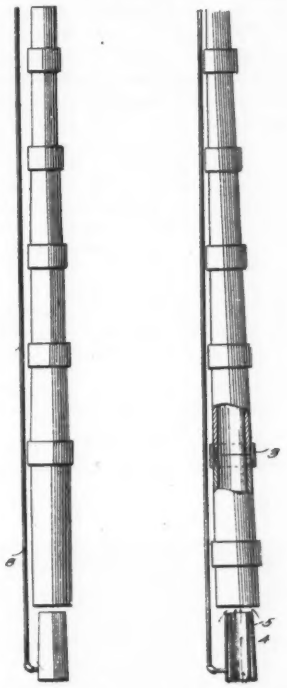
The combination with a water-vessel, of an air-pipe connected therewith, a liquid-discharge extending from the lower portion of the vessel, an escape-pipe extending from the upper portion of the vessel, an inlet-valve having a stem extending upwardly therefrom, and an escape-valve movable simultaneously with said inlet-valve and adapted to reciprocate upon said stem to close said escape-pipe before the seating of the inlet-valve.

697,227. INNER TUBE FOR PNEUMATIC TIRES. Frank A. Wilcox, Erie, Pa., and John R. Gammeter, Akron, Ohio, assignors to Pennsylvania Rubber Company, Erie, Pa., a Corporation of Pennsylvania. Filed Feb. 24, 1902. Serial No. 95,398.

697,403. PROPELLER FOR AIR-SHIPS. Charles Groombridge, London, England, assignor of one-half to William Alfred South, London, England. Filed Feb. 12, 1901. Serial No. 47,034.

697,296. COMPRESSED-AIR WATER ELEVATOR. George R. Tyler, Pomona, Cal. Filed Nov. 25, 1901. Serial No. 83,614.

A compressed-air water-elevator, an eduction-pipe having its bore diminished in diameter from its intake to its discharge end, and means disposed below and spaced from



the lower end of the pipe for discharging a current of air concentrically of the pipe.

697,414. AIR-COMPRESSOR. Frank L. Reeder and Albert B. Freville, Louisville, Ky., assignors to the National Foundry and Machine Company, Louisville, Ky., a Corporation. Filed Feb. 6, 1901. Serial No. 46,203.

An air-compressor, the combination with the taper threaded valve-chamber, having an annular interior groove, and a passage connecting chamber and cylinder, of a taper-threaded double, valve-seat bushing, having a projecting threaded end portion, the valves in said bushing, the perforated jam-nut engaging said projecting portion of the bushing, and the threaded plug engaging a threaded opening in the end wall of the valve-seat chamber.

697,564. PNEUMATIC TIRE. Charles E. Thomas, Tucson, Ariz. Filed Sept. 23, 1901. Serial No. 76,231.

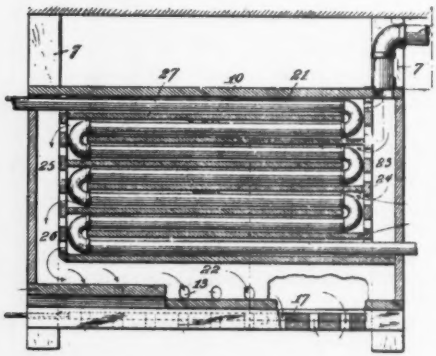
697,567. HYDROPNEUMATIC RENOVATOR. John S. Thurman, St. Louis, Mo. Filed June 22, 1901. Serial No. 65,703.

An apparatus of the character described, the combination with a curtain-wall, of means for projecting liquid against the front face thereof.

697,621. PNEUMATIC VEHICLE-TIRE. Edgeworth Greene, Montclair, N. J., assignor, by mesne assignments, to the American Rubber Works Company, a Corporation of New Jersey. Filed Jan. 4, 1902. Serial No. 88,371.

697,653. PNEUMATIC STACKER. Frederick L. Norton, Racine, Wis. Filed Jan. 6, 1902. Serial No. 88,586.

697,679. AIR-COOLING APPARATUS. Alfred Siebert, St. Louis, Mo. Filed Oct. 4, 1901. Serial No. 77,569.



An air-cooling apparatus, a cooling-box comprising a coil-chamber, having perforated end portions, a cooling-coil arranged within the coil-chamber, partitions arranged between the folds of the coil, a receiving-chamber communicating through one of the perforated partitions with the coil-chamber and a discharge-chamber with which the coil-chamber communicates through the other perforated partition.

697,694. PRESSURE-RETAINING VALVE FOR AIR-BRAKES. John A. Toal, Clancy, Mont., assignor of one-half to Peter Leary, Clancy, Mont. Filed Nov. 29, 1901. Serial No. 83,995.

697,793. PNEUMATIC HAMMER. Joseph Boyer, St. Louis, Mo., assignor to Chicago Pneumatic Tool Company, a Corporation of New Jersey. Filed Nov. 19, 1898. Renewed Jan. 4, 1901. Serial No. 42,121.

A pneumatic hammer comprising a cylinder formed at its front end to receive the shank of the working tool and having a grasping-handle secured to its rear end, a valve-chamber separate from the piston-chamber in said cylinder and located at the rear end thereof, two longitudinal passages in the cylinder-wall communicating at their rear ends with the motive-fluid supply and with the valve-chamber, respectively, a piston-controlling valve located in the valve-chamber, and a hammering-piston located in the piston-chamber and operating at its forward stroke to place the front ends of the two longitudinal passages in communication with each other and thereby admit motive fluid to the valve-chamber to shift the valve in one direction, and operating at its rearward stroke to cut off such communication and open the exhaust from the valve-chamber to permit the valve to be shifted in the opposite direction.

698,012. AIR-ESCAPE VALVE. August Grevel, Cologne, Germany. Filed Sept. 13, 1901. Serial No. 75,349.

An air-escape valve for operating the air-brakes of a car or train from the road-bed, the distinguishing feature of which is that the valve-cap or cylinder-head *h* is fastened to a lever *d* by means of a threaded spindle *f* and through which the cap or cylinder-head *h* is held in place at the end of the cylinder *a* so that the main lever *p* through its roller *o* bears upon the way *m*.

698,170. HOT-AIR FURNACE. William H. Birge, Franklin, Pa. Filed July 5, 1901. Serial No. 67,160.

A hot-air furnace comprising a casing having to one side of the same a fire-pot and on the opposite side an exit for the products of combustion, a plurality of vertically-disposed hot-air tubes carried by top and bottom plates, a dome or top for the reception of the heated air, and a perforated baffle or heat-restraining plate located within the casing and positioned nearer the opening for the exi of the products of combustion than to the fire-pot.

698,236. HYDRAULIC AIR-COMPRESSOR. Joseph Weyand, Guttenberg, N. J. Filed Dec. 18, 1901. Serial No. 86,445.

The combination with a shell having water inlet and outlet openings a lever pivoted within the shell, two valves controlling the said openings and connected with said lever and a vertical rod connected at its lower end with the said lever and provided with vertically-sliding floats the lower float having a limited upward movement on the rod to raise it, of air-delivery and air-vent in the upper end of the shell and a valve covering the air-vent raised by the direct action of the upper float.

698,362. MEANS FOR COMPRESSING OR LIQUEFYING GASES. Bruce Borland, Cambridge, Mass. Filed June 7, 1900. Serial No. 19,392.

Means for compressing and liquefying gas, which consist in a compressing-cylinder open at its bottom, a gas-receiver carried by the upper portion of the cylinder, a communication between the gas-receiver and cylinder, which communication is normally closed by a valve opening inwardly in the receiver, the said receiver being provided with a circumferential chamber between its inner and outer walls in communication with the main chamber, and means for drawing off the compressed gas from the receiver.

698,538. CLUTCH FOR PNEUMATIC HAMMERS. Albert C. Murphy, East St. Louis, Ill., assignor to Standard Railway Equipment Company, a Corporation of Illinois. Filed May 17, 1901. Serial No. 60,694.

A clutch for pneumatic hammers comprising clamping-jaws and a resilient split ring encircling them, said jaws being adapted to be mounted upon a pneumatic hammer.

698,710. AIR-PUMP. George W. Kellogg, Hartford, Conn. Filed Feb. 13, 1901. Serial No. 47,162.

An air-pump, the two cylinders of unequal diameters, the smaller one being mounted end to end upon the other and at one side of its center, a piston in each cylinder having a hollow rigid connection with that in the other whereby the cylinders may communicate, and mechanism for moving the pistons mounted upon the side of the smaller cylinder and connected through the end of the larger cylinder to its piston.

698,830. PNEUMATIC-DESPATCH TUBE. Edmond A. Fordyce, Chicago, Ill. Filed Feb. 14, 1902. Serial No. 94,144.

A pneumatic-tube system, the combination with an overhead main-line tube adapted to transmit carriers from an outlying station to the cash-desk, of a looped branch connected with and depending from said main-line tube at a local sending-station, a valve at the junction of said main tube and branch normally deflecting the current through the latter but permitting the uninterrupted travel of through-carriers past the junction, and a sending-terminal located in said looped branch.

698,900. CLAMP FOR ROCK-DRILLS. Frank R. Brown, Unga, Alaska. Filed July 18, 1901. Serial No. 68,794.

698,905. VALVE FOR PNEUMATIC MUSICAL INSTRUMENTS. Melville Clark, Chicago, Ill. Filed July 23, 1901. Serial No. 69,349.

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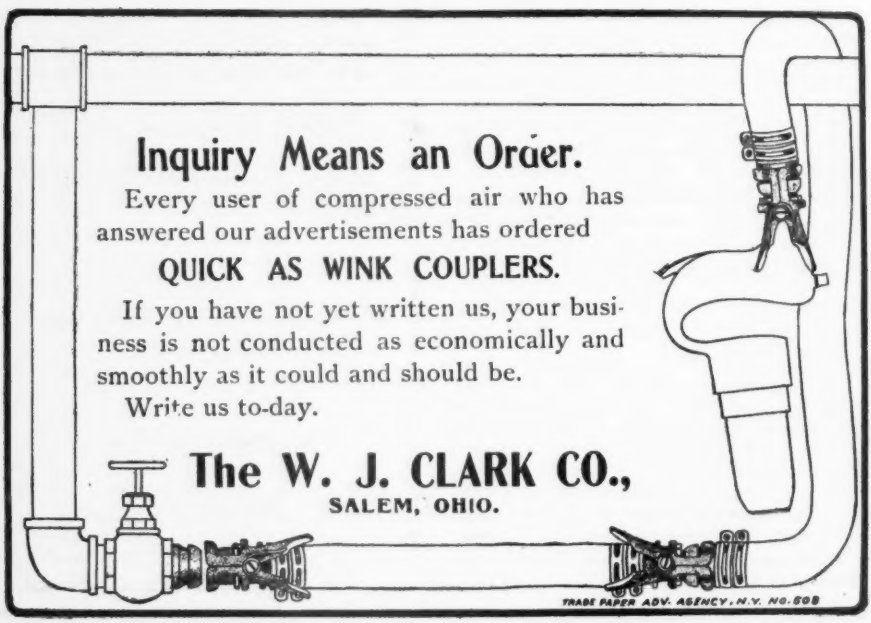

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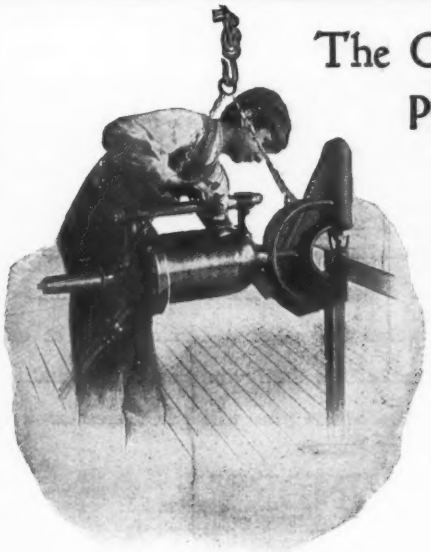

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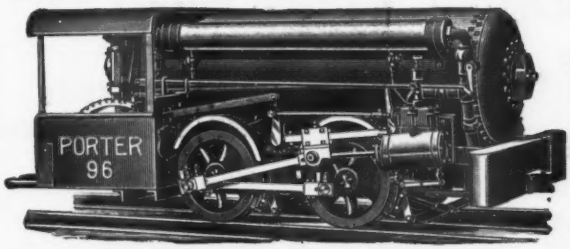

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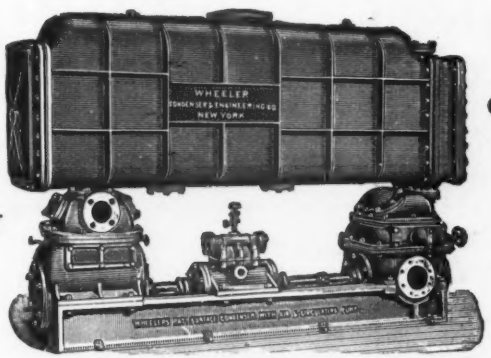

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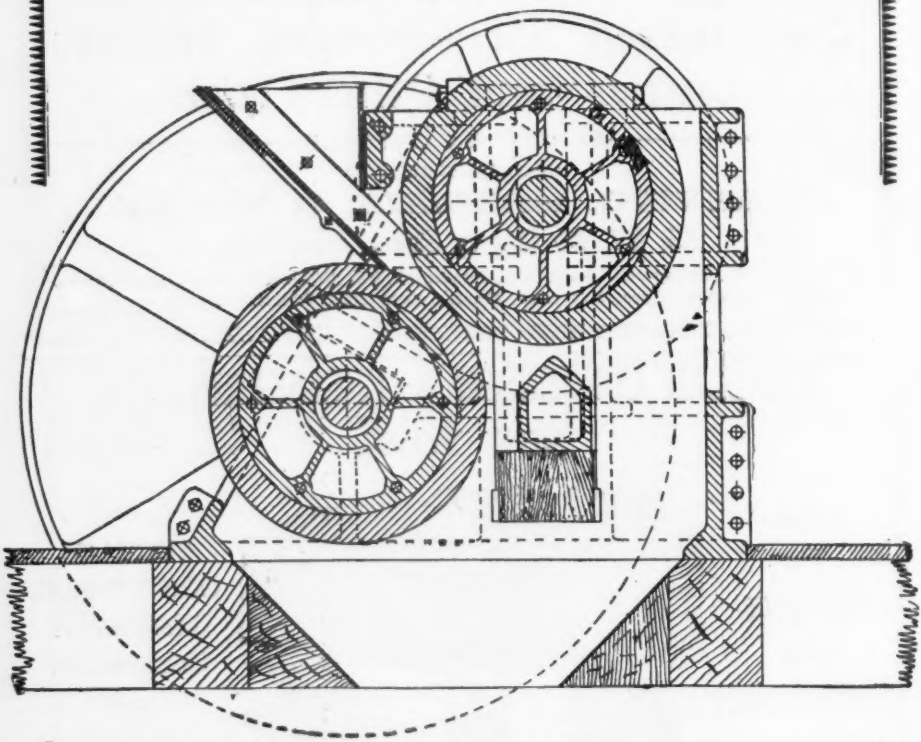

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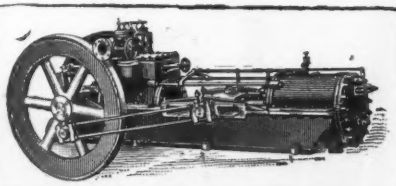

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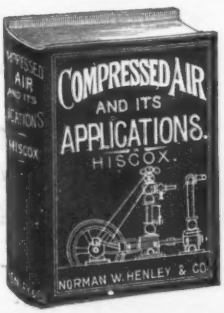

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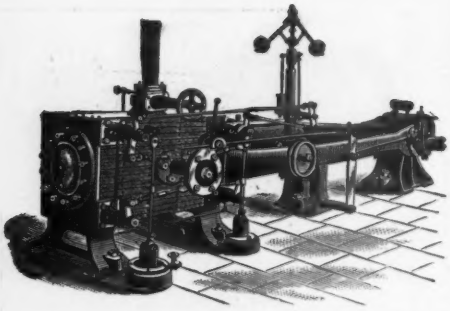

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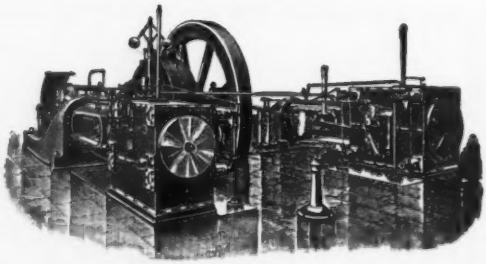

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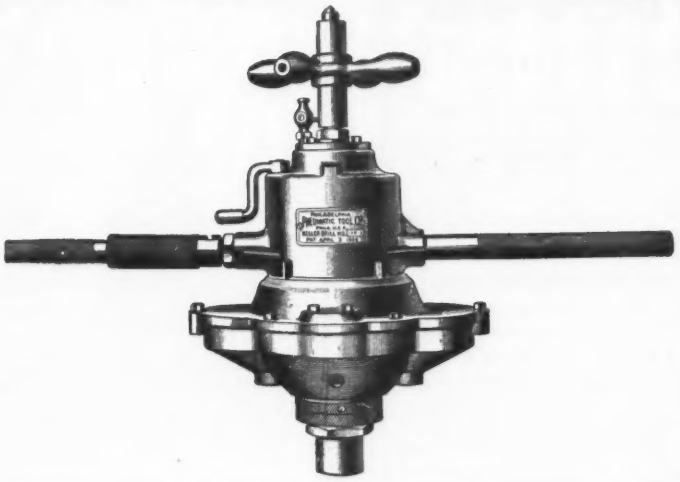

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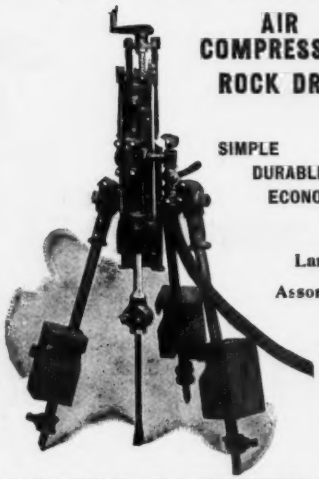

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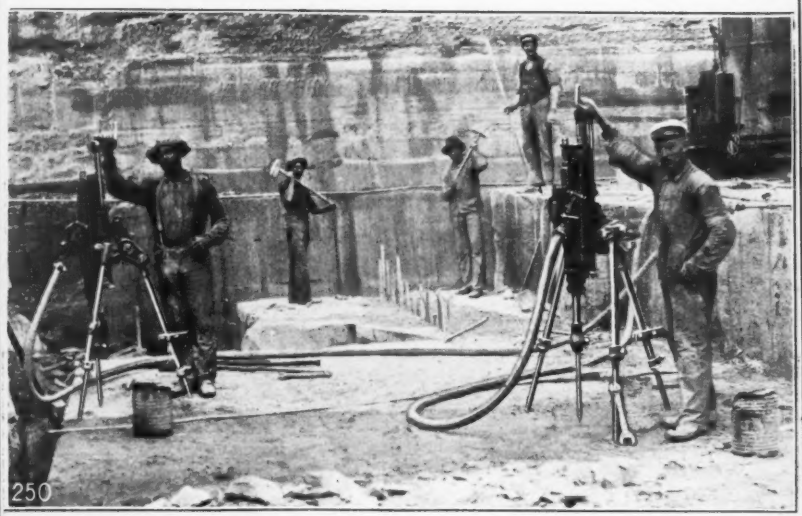

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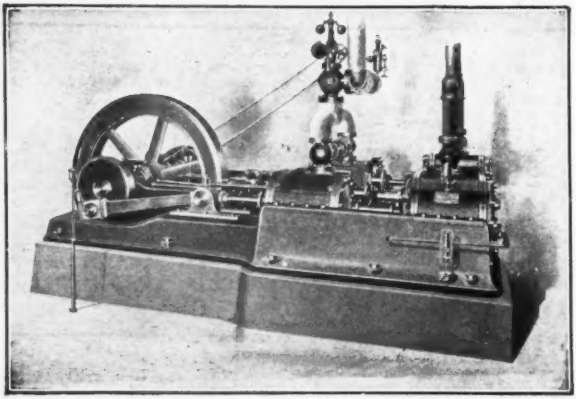

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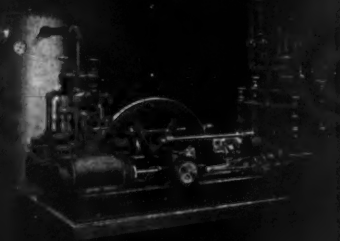

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